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CNG ENGINE DURABILITY TEST

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DISCLAIMER

This study was carried out with the cooperation of the Department of Energy, Mines and Resources. However, the views expressed in the report are those of the author and do not necessarily reflect the views of the Department.

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1. INTRODUCTION

Canada is taking a leading role in the introduction of Compressed Natural Gas (CNG) as a fuel for automotive application. CNG is an excellent fuel for a reciprocating, spark-ignited (S.I.) engine with the potential for low emissions and higher thermodynamic efficiency as compared to a gasoline fuelled engine. The Federal Government of Canada further recognizes its potential as an alternative to gasoline in balancing energy supply to the transportation sector and the increased use of indigenous resources.

The introduction of CNG, however, is initially accomplished through the aftermarket. Retrofit kits, consisting of CNG storage tanks, regulators and a fuel mixer, are added to an existing engine to enable use of this fuel with the option of switching back to gasoline if the alternative fuel is not readily available. Although this dual fuel approach has inherent disadvantages, since the engine cannot be optimized for NG, it is a vital step in the introduction of NG as an automotive fuel.

2. RATIONALE AND OBJECTIVES OF STUDY

Some problems have been experienced in these early applications of NG manifested in the form of excessive wear, cold start problems, and poor fuel economy. These were, in part, due to lack of proper conversion equipment (e.g. a few mixer kits were fitted to a broad range of engines, lack of detailed spark schedule development work), in part, due to improper materials in the engines, in particular exhaust valve wear. Similar problems were experienced during the introduction of propane, which, similar to natural gas, is introduced into the engine in gaseous form. The major engine manufacturers recognized these problems as well and - in partial support of the Federal Government - have introduced changes to the cylinder heads and valves in the form of seat inserts and harder valves (e.g. stellite)*. These modifications have greatly reduced valve wear.

Since no systematic data were available on performance of these components on natural gas, the Federal Government through B.C. Research, stipulated a program to evaluate a typical automotive gasoline fuelled S.I. engine on natural gas, using modified cylinder heads. The objective was to generate systematic data on the change in wear of an S.I. engine operated on NG, in order to further our understanding of the wear mechanism and to be able to recommend to potential users hardware with good performance potential. Premature engine wear could significantly affect further efforts in introducing CNG as a fuel for transportation.

* Optimization of Propane Engines for Light Duty Vehicles - Phase I, prepared for Transport Canada, Transportation Development Centre, by Chrysler Canada Ltd., March 1984, Report #TP5171E.

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Fuel system performance and optimization of spark timing were not part of this program but are addressed in separate programs sponsored by the Federal Government.

3. TEST ENGINE AND TEST PROCEDURES

The test engine was a 5.7 L V8 spark-ignited gasoline engine supplied by General Motors of Canada, (GMC) Ltd. The engine was fully dressed and in a ready to run condition (including ignition system, carburettor, air cleaner, alternator). Technical details of the engine are given in Table 1.

In order to operate the engine on natural gas, a commercially available NG fuel system suitable for this engine was made available by CNG Fuel Systems Ltd., Toronto, and installed on the engine. Spark timing was adjusted by incorporation of a Dual Curve spark box. Details of the components comprising the NG retrofit kit are given in Table 2. Appendix A contains a brochure by CNG describing details of the NG fuel system and its installation and calibration. The installation of the components was carried out by CNG Fuel System personnel. The approach was to simulate acquisition of an engine (or vehicle) with subsequent retrofit for operation on natural gas.

A critical set of hardware was the cylinder heads. Two sets of spare cylinder heads were procured. Whilst one set was for standard non-leaded gasoline use, the other set was factory-modified, with exhaust valve seat inserts and standard exhaust valves (this heavy duty engine has some stellite coating on the exhaust valve faces). The rationale was to fit one bank of the engine with a standard head, the other bank with a modified head, in order to maximize the information. For comparison purposes, GMC would make available to the Project Authority, baseline data on gasoline.

In order to make valve wear data comparable to GMC results, the same test procedures as employed by GMC were adopted. The accelerated wear test cycle consisted of WOT operation with the speed varying in a sinusoidal pattern between 3700 and 4200 RPM, cycle duration, one minute. After fifteen cycles, a one minute idle period at 1600 RPM would be interjected. A pattern of this cycle is shown in Figure 1.

Data to be collected during testing, were valve recess as measured every 25 hours of engine operation, compression checks performed every 8 to 10 hours and monitoring of engine speed and load, intake and exhaust temperatures (each individual exhaust port), oil and coolant temperature and combustion air temperature (air intake snorkel). Further monitoring activities, as found necessary during the test sequences, are given in Table 3.

4. ENGINE SET-UP AND INSTRUMENTATION

The 5.7 L engine was set up in Test Cell #3 at ORF on a Go-Power engine stand. A 512 Go Power water brake was attached to the engine via a bell housing and a splined shaft. Engine speed and load was monitored and controlled through a GPS 1000 controller. Transient testing was accomplished with a programmable module connected to the GPS 1000 controller.

Fuel was supplied to the engine through a 40 psi NG supply line. Two Lando Renzi regulators were used in parallel, bypassing the high pressure stage, in order to provide sufficient fuel. The exit fuel lines were connected with a "Y" and fed to the mixer. The power adjustment valve was located just before the mixer. The power adjustment valve was set to read 0.7% CO at WOT @ 3000 RPM.

Engine coolant temperature was controlled by a GP cooling tower regulating temperature at 75°C. Manifold vacuum was monitored continuously with a mercury manometer. Another mercury manometer was used to monitor exhaust backpressure adjusted to 18" Hg at 3000 RPM @ WOT with a fixed orifice in the test cell exhaust system. A set-up of the engine in Test Cell #3 at ORF is shown in Figure 2.

Type K thermocouples were installed on the engine to monitor:

- exhaust temperatures in each exhaust port;
- oil temperature (not to exceed 140°C);
- air intake temperature at intake snorkel of air cleaner (not to exceed 30 °C);
- ambient test cell temperature (not to exceed 45°C).

Oil pressure was monitored continually via a 0 - 100 psi pressure gauge mounted on the engine.

Engine speed and load were continually monitored with a 2-pen strip chart recorder.

The dynamometer controller incorporated a safety shut-down board monitoring engine speed, oil pressure, intake temperature, manifold pressure (e.g. back fire resulting in positive manifold pressure).

A special fixture was provided by GMC to measure valve recess. This fixture and its application is shown in Figure 4. Valve recess was measured as follows. After removal of the valve cover, the rocker arms were removed. The fixture is put over the rocker stuts (centering) and rests on 3 points of the cylinder head on machined surfaces. The top surface of the fixture is machined providing access to the intake and exhaust. With a

depth micrometer, the distance from the reference surface to the top of the valve stem is measured. Valve recess is determined as the change between subsequent readings. Accuracy was + 0.0005".

All instrumentation and equipment was calibrated prior to commencement of testing to within 2% accuracy.

5. TEST SEQUENCES AND RESULTS

5.1 Torque Curves

After completion of engine installation, the engine was broken in on gasoline according to the schedule shown in Table 4. Thereafter, prior to installation of the CNG fuel system a torque curve on gasoline was generated with and without control of exhaust back pressure. The torque and power curve of the OEM engine on gasoline is shown in Figure 3. Subsequent to the installation of the CNG fuel system components, additional torque curves were run with the following configurations:

- on gasoline with CNG in place, no back pressure;
- on CNG, without back pressure;
- on CNG with back pressure.

The results are summarized in Table 5.

The durability tests were planned in two sequences, Sequence 1 consisting of 250 hours on straight natural gas, Sequence 2 with 90% operation (4.5 hours) on NG and 10% operation (0.5 hours) on gasoline for 250 hours. Each time one bank was fitted with a standard head, while the other bank was fitted with a modified cylinder head (exhaust valve seat inserts). This test design was to provide maximum information on valve wear and the potential effect of intermittent use of gasoline which does take place in reality.

5.2 Test Sequence 1

After completion of the torque curves, the original heads used for engine break-in were removed and replaced with the test heads. The oil was changed. Valve tip measurements were performed and the values recorded. Subsequently, testing commenced. Valve tip readings and resulting valve recess and compression check data are given in Tables 6, 7 and 8, respectively. Due to excessive exhaust valve wear on the standard head, testing had to be stopped after 200 hours. The valve wear and compression check data are graphically displayed in Figures 5 and 6, respectively. The cylinder heads were removed and the valve wear analyzed. Pictures of the valves and valve seats were taken and are shown in Figures 7 through 11.

5.3 Test Sequence 2

A new set of heads was installed on the engine after inspection of the cylinder bores which did not show any wear. Testing commenced, and proceeded similar to Test Sequence 1, except that after every 4.5 hours on NG the engine was operated on gasoline for 0.5 hours. After the first switch-over to gasoline, it was found that maximum power was not attainable. The problem was traced to the mixer which posed too much restriction in the air intake. As a result, the CNG mixer was replaced with a mixer supplied by Diversified Fuel Systems (DFS), Windsor, which has a larger air opening when operating on gasoline. The power valve needed only minor adjustment to maintain CO at 0.7% level. During the switch-over process, the engine had to be operated at low idle to prevent potential over-fuelling or an engine run-away situation. Again, valve tip measurements and compression checks were performed at the indicated intervals. The results are summarized in Tables 9, 10 and 11, respectively. Exhaust gas temperatures, as recorded routinely, are collected in Table 12. At 180 hours into the test, an exhaust valve of a modified head failed, resulting in the premature termination of the testing. An analysis of the break indicated a fatigue crack, not necessarily associated with operation on natural gas. Valve wear rates and compression check results are shown in Figures 12 and 13. The cylinder heads were removed from the engine and valves and valve seats analyzed. A photographic documentation of the valves and seats for Test Sequence 2 is given in Figures 14 through 18.

6. DISCUSSION

6.1 Valve Recess Intake Valves

The intake valves of both the standard and modified head on both test sequences showed similar rate of wear of about 0.010" per 100 hours, which then flattened out to a rate of about 0.005" per 100 hours. This slow-down is due to the complete seating of the valves after the first 75 to 100 hours of engine operation. The observed wear rate is normal and acceptable for in-field use. Figures 5 and 12 confirm these observations.

6.2 Valve Recess Exhaust Valves

It became clear after only 50 hours of testing on each test sequence, that the standard exhaust valves did display excessive wear, which was further confirmed over the duration of the 200 hours. Wear rates in Test Sequence 1 were about 0.055" per 100 hours, which after about 100 hours, showed a decline to about 0.040 per 100 hours. In Test Sequence 2 (operating on gasoline), a similar initial pattern over the first 100 hours was observed, but instead of slowing down, the wear rate was maintained at about 0.050" per 100 hours. A reason for this may be found in the slightly higher exhaust temperatures which were observed when operating on gasoline.

Evaluating Figures 9 and 15, it is found that the exhaust valves wear into the seats. Wear is exclusively on the seats, while the valves themselves maintain their shape. This would indicate that the seat area is too soft.

The cylinder heads with the modified exhaust valves (consisting of seat inserts and harder valves) show a wear rate in both test sequences which is similar to that of the intake valves (Figures 5 and 12). This would indicate that an acceptable performance of these valves could be expected over the life of the engine. A close-up of these valves and seats (Figures 11 and 18) confirms this observation.

During Test Sequence 2, at 174 hours, a failure of an exhaust valve was encountered. This resulted in premature termination of the test. The failure (break of valve stem near the valve) was analyzed and it is believed that the break was due to material fatigue. The microscopic analysis further indicated that the valve seat area was coated with a layer of harder material (Figure 19). Closer examination of this valve seat cross-section and complementary seat insert also indicated that the wear (or recess) does occur primarily on the valve seat and not on the seat insert. A modification in hardness of the materials for seat insert and valve seat, may be required to have wear occur more evenly on both contact surfaces.

6.3 Compression Check Data

In this context, the compression check data (primarily of Test Sequence 1) would suggest that compression pressure is lost at a higher rate on the modified head. This may partially be explained by loss of sealing of the modified valve/seat insert combination (may be due to uneven wear as discussed in Section 6.2). The standard exhaust valves, although displaying much higher wear, seem to maintain their sealing capacity and loss of compression pressure may primarily be due to valve recess. These data, however, have to be interpreted carefully, since fluctuations in cranking speed during a compression check can greatly affect the results.

6.4 Additional Observations

Inspection of cylinder bores at change-over of heads (between test sequences) did not show any excess wear. After the first 200 hours, some hone marks were still visible while after additional 175 hours, only slight scuffing marks were observed. It is estimated that the engine block would be suitable for at least an additional 200 hours of testing.

Only slight deposits were found on the pistons, and the combustion chambers in the heads were absolutely clean (Figures 7 and 14).

Lubricant used in the tests was a 10 W 30 grade for gasoline-fuelled S.I. engines and was changed every 100 hours of testing.

TABLE 1

SPECIFICATIONS OF TEST ENGINE

Manufacturer	Chevrolet (GMCL)
Displacement	350 CID (5.7 L)
Configuration	V8
Bore	4.00" (10.16 cm)
Stroke	3.480" (8.84 cm)
CR	8.3:1
Firing Order	1-8-4-3-6-5-7-2
Rated H.P.	160 H.P. @ 3800 RPM
Peak Torque	250 lbs./ft @ 2800 RPM
Fuel System	4 Barrel Rochester Carburettor (quadrajet).
Application	LT9 pick-up truck (heavy duty)
Emission Control	Exhaust Manifold Air Injection.

TABLE 2

COMPONENTS OF CNG RETROFIT FUEL SYSTEM FOR TEST APPLICATION

1	Fixed Venturi Mixer, Model -, adapted on top of carburettor in air cleaner housing.
2	Lando Renzi Pressure Regulators bypassing high pressure stage, mounted parallel, to supply sufficient fuel.
1	Dual Curve Spark Advance Box.
1	Fuel shut-off solenoid in gasoline supply line.
2	Vacuum switches for lift plate on mixer.
1	Dashboard switch for dual fuel operation.

TABLE 3

ENGINE MONITORING ACTIVITIES DURING ACCELERATED WEAR TESTING.

Check	Interval	Actions
Valve Stem height	1. 0 hrs. 2. Every 25 hrs.	When valve recess exceeds 0.050" consult test engineer.
Timing Check	1. 0 hrs. 2. Every 50 hrs.	Reset initial timing if outside the range of ± 2 degrees.
Compression Check	1. 0 hrs. 2. Every 8 hrs.	Check for minimum cylinder pressure, consult test engineer if below set limit.
Spark plugs	Every 50 hrs.	
Spark Plug Gap	1. 0 hrs. 2. Every 50 hrs. 3. Whenever removed.	Check gap, but do not reset; replace plugs as required.
Oil level	Every 8 hrs.	
Oil change with filter change.	Every 100 hrs.	

TABLE 4

SCHEDULE FOR ENGINE BREAK-IN

RPM	TORQUE	TIME
1600	25 ft/lb	3/4 hour
1600	50	3/4 hour
2000	25	3/4 hour
2000	50	3/4 hour
2400	25	3/4 hour
2400	75	3/4 hour
2800	50	3/4 hour
2800	100	3/4 hour
3200	75	3/4 hour
3200	125	3/4 hour
3600	100	3/4 hour
3600	WOT	3/4 hour
4000	100	3/4 hour
4000	WOT	1 hour
		10.75 hours

TABLE 5

Comparison of Torque (Lb·Ft) for 350 CID Chevrolet
on Gasoline (Super Non-Leaded, SNL) and Natural Gas (NG)

	Super Non-Leaded Gasoline					Natural Gas	
RPM	Stock[1] 1" Hg EBP	NG Mixer[2] installed 1" Hg EBP	NG Mixer installed 20" Hg EBP	NG Mixer air cover rem. 1" Hg EBP	NG Mixer air cover rem. 20" Hg EBP	NG Mixer[2] installed 1" Hg EBP	NG Mixer[2] installed 20" Hg EBP
2000	-	-	212	-	-	212	205
2200	245	-	213	-	-	212	200
2400	252	-	210	250	230	213	198
2600	252	244	205	258	235	213	196
2800	255	245	200	260	230	212	188
3000	252	243	195	255	225	210	183
3200	247	235	190	252	218	205	178
3400	245	230	180	248	210	200	170
3600	237	220	175	240	200	195	160
3800	228	210	160	230	190	186	152
4000	215	206	145	220	175	178	140
4200	202	-	135	208	165	165	130

(1) EBP Exhaust Backpressure

(2) As supplied by CNG Fuel Systems

TABLE 6

Valve Tip Readings,
Test Sequence 1.

Time	(Hours)									
	0	2	23.5	48	75	100	123	150	175	200
	08/29	09/05	09/09	09/18	09/23	09/30	10/04	10/09	10/21	10/24
Intake										
L1	1.020	1.017	1.013	1.011	1.010	1.011	1.009	1.011	1.009	1.006
L2	1.010	1.008	1.006	1.006	1.004	1.004	1.003	1.003	1.004	1.001
L3	0.999	1.001	0.990	0.989	0.989	0.984	0.979	0.979	0.976	0.973
L4	0.999	0.993	0.992	0.989	0.988	0.988	0.988	0.988	0.989	0.987
R1	1.023	1.021	1.022	1.012	1.013	1.011	1.013	1.013	1.009	1.006
R2	1.015	1.014	1.009	1.008	1.007	1.007	1.004	1.007	1.007	1.001
R3	1.017	1.013	0.999	0.998	0.997	0.996	0.997	0.999	0.997	0.991
R4	1.027	1.025	1.016	1.015	1.013	1.013	1.012	1.009	1.009	1.007
Exhaust										
L1	1.024	1.023	1.022	1.020	1.016	1.013	1.011	1.010	1.009	1.004
L2	1.006	1.003	1.002	0.998	0.997	0.992	0.988	0.988	0.983	0.978
L3	1.000	0.992	0.997	0.994	0.990	0.989	0.988	0.988	0.985	0.981
L4	1.005	1.002	0.999	0.997	0.995	0.996	0.994	0.993	0.988	0.988
R1	1.029	1.030	1.012	0.988	0.964	0.954	0.937	0.912	0.907	0.903
R2	1.010	1.010	0.998	0.977	0.970	0.963	0.950	0.943	0.939	0.925
R3	1.010	1.011	0.990	0.976	0.964	0.956	0.951	0.940	0.935	0.921
R4	1.017	1.017	1.008	0.991	0.981	0.972	0.966	0.962	0.955	0.949

TABLE 7

Valve Recess Data,
Test Sequence 1

	0-2	0.23.5	0-48	0-75	0-100	0-123	0-150	0-175	0-200
Intake									
L1	.003	.007	.009	.010	.009	.011	.009	.011	.014
L2	.002	.004	.004	.006	.006	.007	.007	.006	.009
L3	-.002	.009	.010	.010	.015	.020	.020	.023	.026
L4	.006	.007	.010	.011	.011	.011	.011	.010	.012
$\bar{X}$	.00225	.00657	.00825	.00925	.010 (±.004)*	.012 (±.006)	.012 (±.006)	.0125 (±.001)	.015 (±.005)
R1	.002	.001	.011	.010	.012	.010	.010	.014	.017
R2	.001	.006	.007	.008	.008	.011	.008	.008	.014
R3	.004	.018	.019	.020	.021	.020	.018	.020	.026
R4	.002	.011	.012	.014	.014	.015	.018	.018	.020
$\bar{X}$	.00225	.009	.01225	.013	.014 (±.005)	.014 (±.005)	.014 (±.005)	.015 (±.004)	.019 (±.007)
Exhaust									
L1	.001	.002	.004	.008	.011	.011	.014	.015	.020
L2	.003	.004	.008	.009	.014	.018	.018	.023	.028
L3	.008	.003	.006	.010	.011	.012	.012	.015	.019
L4	.003	.006	.008	.010	.009	.011	.012	.017	.017
$\bar{X}$	.00375	.00375	.0065	.00925	.011 (±.002)	.013 (±.003)	.014 (±.005)	.018 (±.007)	.021 (±.001)
R1	.000	.017	.041	.065	.075	.092	.117	.122	.126
R2	.000	.012	.033	.040	.047	.060	.067	.071	.085
R3	.001	.020	.034	.046	.054	.059	.070	.075	.089
R4	.000	.009	.026	.036	.045	.051	.055	.062	.068
$\bar{X}$	.00025	.0145	.0335	.04675	.055 (±.014)	.066 (±.018)	.077 (±.021)	.0825 (±.023)	.092 (±.026)

* Indicates Standard Deviation

TABLE 8

Compression Check Data,
Test Sequence 1.

DATE & ENG. HRS.	L1	L2	L3	L4	$\overline{X}$	R1	R2	R3	R4	$\overline{X}$
09/03 36.5	135	145	132	160	143	145	145	150	160	150
09/04 43.5	120	142	135	137	133.5	127	145	150	149	142.75
09/16 52.5	125	148	137	140	137.5	155	142	155	152	152
09/17 65.5	125	150	143	146	141	156	139	150	155	150
09/17 68	132	155	140	153	145	140	155	162	163	155
09/18 71.5	150	150	133	141	143.5	165	158	155	165	160.75
09/19 80	125	145	126	145	135.25	160	145	149	159	153.25
09/20 94	107	137	130	138	128	160	152	150	152	153.5
09/28 118	125	130	135	150	135	160	145	145	155	151.25
10/01 127	115	140	125	125	126.25	135	130	120	125	130
10/02 133	120	155	135	145	138.75	130	145	140	145	140

....2/..

TABLE 8 (cont'd.)

Compression Check Data,
Test Sequence 1.

DATE & ENG. HRS.	L1	L2	L3	L4	$\bar{X}$	R1	R2	R3	R4	$\bar{X}$
10/03 139	105	155	140	150	137.50	110	125	135	140	127.5
10/07 158	110	160	145	140	138.75	130	145	130	150	138.75
10/07 170	175	145	135	125	145	100	110	100	120	107.5
10/15 176	100	125	110	120	113.75	100	105	115	100	105
10/16 184	90	115	105	105	103.75	75	90	70	70	76.25
10/17	NEW STARTER MOTOR INSTALLED									
10/18 195	100	130	130	140	125	95	120	100	115	107.50

TABLE 9

Valve Tip Readings,

Test Sequence 2.

Date	10/28	11/14	11/21	11/26	11/28	12/04	12/12	01/06
Hours	0	25	50	80	100	120	144	169
Intake								
L1	1.012	1.008	1.005	1.000	1.006	1.004	1.004	1.003
L2	1.004	1.000	0.998	0.995	0.998	9.997	0.996	0.996
L3	1.005	0.995	0.993	0.994	0.993	0.993	0.992	0.992
L4	1.014	1.010	1.006	1.006	1.007	1.006	1.006	1.005
R1	1.013	1.006	1.001	1.006	1.004	1.002	1.003	0.999
R2	1.006	1.003	1.000	1.000	0.999	0.999	0.999	0.998
R3	1.002	0.983	0.980	0.919	0.978	0.977	0.977	0.975
R4	1.005	0.996	0.994	0.993	0.993	0.992	0.993	0.985
Exhaust								
L1	1.021	1.019	1.014	1.013	1,012	1.011	1.010	-
L2	1.006	1.003	0.998	0.997	0.996	0.993	0.989	0.989
L3	1.013	1.006	0.998	0.996	0.995	0.991	0.991	0.990
L4	1.017	1.014	1.010	1.010	1.010	1.010	1.001	1.004
R1	1.016	0.992	0.971	0.957	0.949	0.934	0.912	0.887
R2	1.018	0.980	0.960	0.948	0.934	0.928	0.915	0.891
R3	1.013	0.980	0.960	0.948	0.934	0.928	0.915	0.891
R4	1.001	0.997	0.981	0.961	0.953	0.9440.935		0.921

TABLE 10

Valve Recess Data,

Test Sequence 2.

Date Hours	11/14 0-25	11.21 0-50	11/26 0-80	11/28 0-100	12/04 0-120	12/12 144	01/06 169
Intake							
L1	.004	.007	.012	.006	.008	.008	.009
L2	.004	.006	.009	.006	.007	.008	.008
L3	.010	.012	.011	.012	.012	.013	.013
L4	.004	.008	.008	.007	.008	.008	.009
$\bar{X}$	.0055	.00825	.010	.008	.009	.009	.010
R1	.007	.012	.007	.009	.011	.010	.014
R2	.003	.006	.006	.007	.007	.007	.008
R3	.019	.022	.023	.024	.025	.025	.027
R4	.009	.011	.012	.012	.013	.012	.020
$\bar{X}$	.0095	.01275	.014	.013	.014	.013	.017
Exhaust							
L1	.002	.007	.008	.009	.010	.011	-
L2	.003	.008	.009	.010	.013	.017	.017
L3	.007	.015	.017	.018	.022	.022	.023
L4	.003	.007	.007	.007	.007	.010	.013
$\bar{X}$	.00375	.00925	.010	.0115	.0125	.015	.017
R1	.024	.045	.059	.067	.082	.104	.129
R2	.038	.058	.070	.084	.090	.103	.127
R3	.039	.060	.076	.083	.090	.098	.115
R4	.010	.026	.046	.054	.063	.072	.086
$\bar{X}$	.02775	.04725	.0623	.072	.081	.094	.114

TABLE 11

Compression Check Data,

Test Sequence 2.

	L1	L2	L3	L4	$\bar{X}$	R1	R2	R3	R4	$\bar{X}$
11/11 6-1/2	140	155	140	145	145	135	140	140	145	140
11/12 12-1/2	135	145	140	135	139	130	145	135	145	139
11/13 * 15	135	140	140	135	138	135	145	135	140	138
22	New starter installed on engine									
11/19 25	165	175	175	170	171	165	165	170	170	168
11/20 32.5	165	180	175	170	173	170	175	170	175	172
11/20 50	170	175	175	175	174	170	175	170	170	171
11/26 80	160	180	165	160	166	170	175	160	170	169
11/29 102	165	180	170	165	170	150	165	165	175	164
12/02 107	160	175	170	160	166	155	155	160	175	161
12/03 120	165	175	175	155	168	140	145	160	175	155
12/20 156	165	175	160	145	161	140	135	120	170	141

TABLE 12

EXHAUST TEMPERATURE DATA
(° Celsius)
Test Sequence 1: Straight Natural Gas,
(CO in Exhaust 0.7%).

Cylinder / Hr.	1	2	3	4	5	6	7	8
2	810	743	785	798	832	783	775	800
25	802	740	796	794	830	779	761	791
50	796	723	774	786	830	778	752	793
100	805	741	798	802	833	777	729	769
150	798	740	802	794	873	795	735	772
200	791	753	825	808	857	791	737	772

Test Sequence 2: NG, Gasoline (10%)

Cylinder / Hr. Fuel	1	2	3	4	5	6	7	8
2 NG*	825	756	801	735	834	809	795	716
G	754	760	783	681	771	740	712	788
50 NG	772	732	793	660	793	719	739	765
G	841	767	823	752	812	824	818	785
100 NG	801	740	818	702	814	742	724	771
G	858	772	852	783	788	840	824	798
150 NG	775	727	802	730	798	755	737	754
G	759	763	812	815	804	808	746	770

* NG = Natural Gas
G = Gasoline.

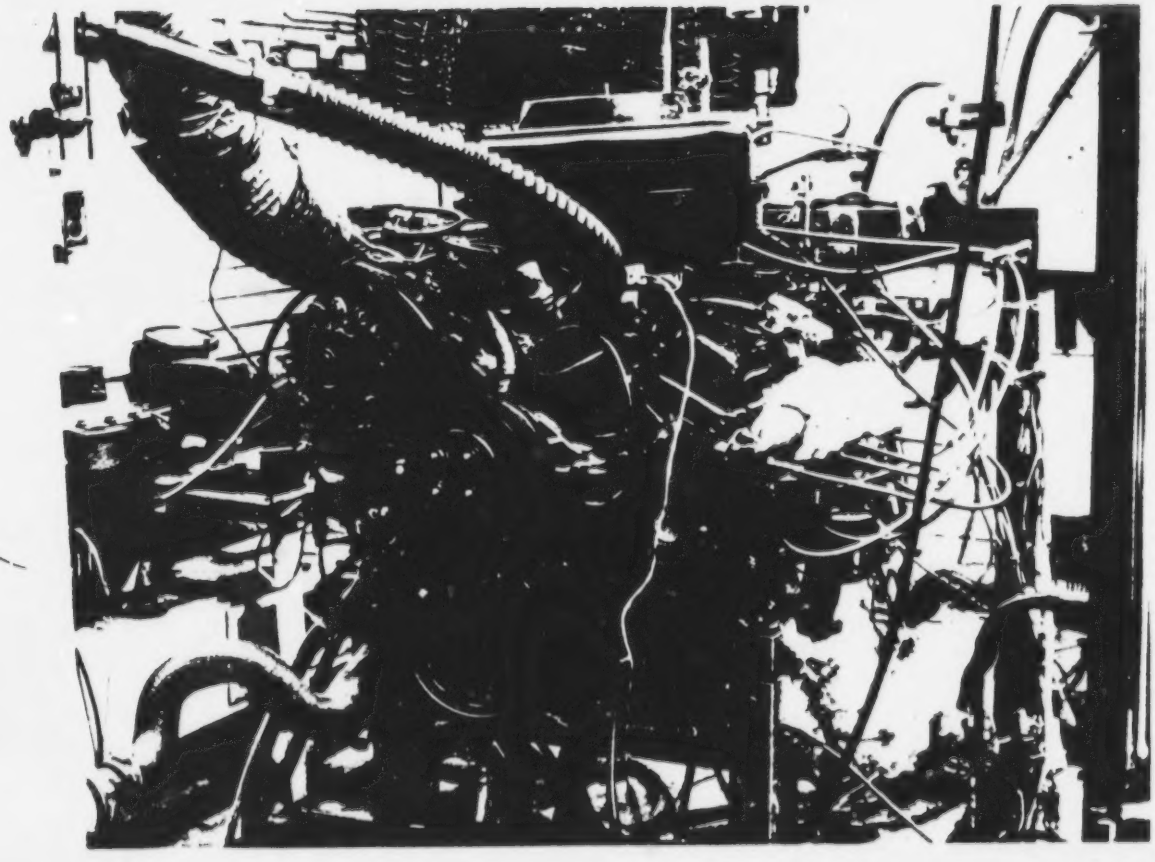


FIGURE 2

TEST ENGINE SET-UP

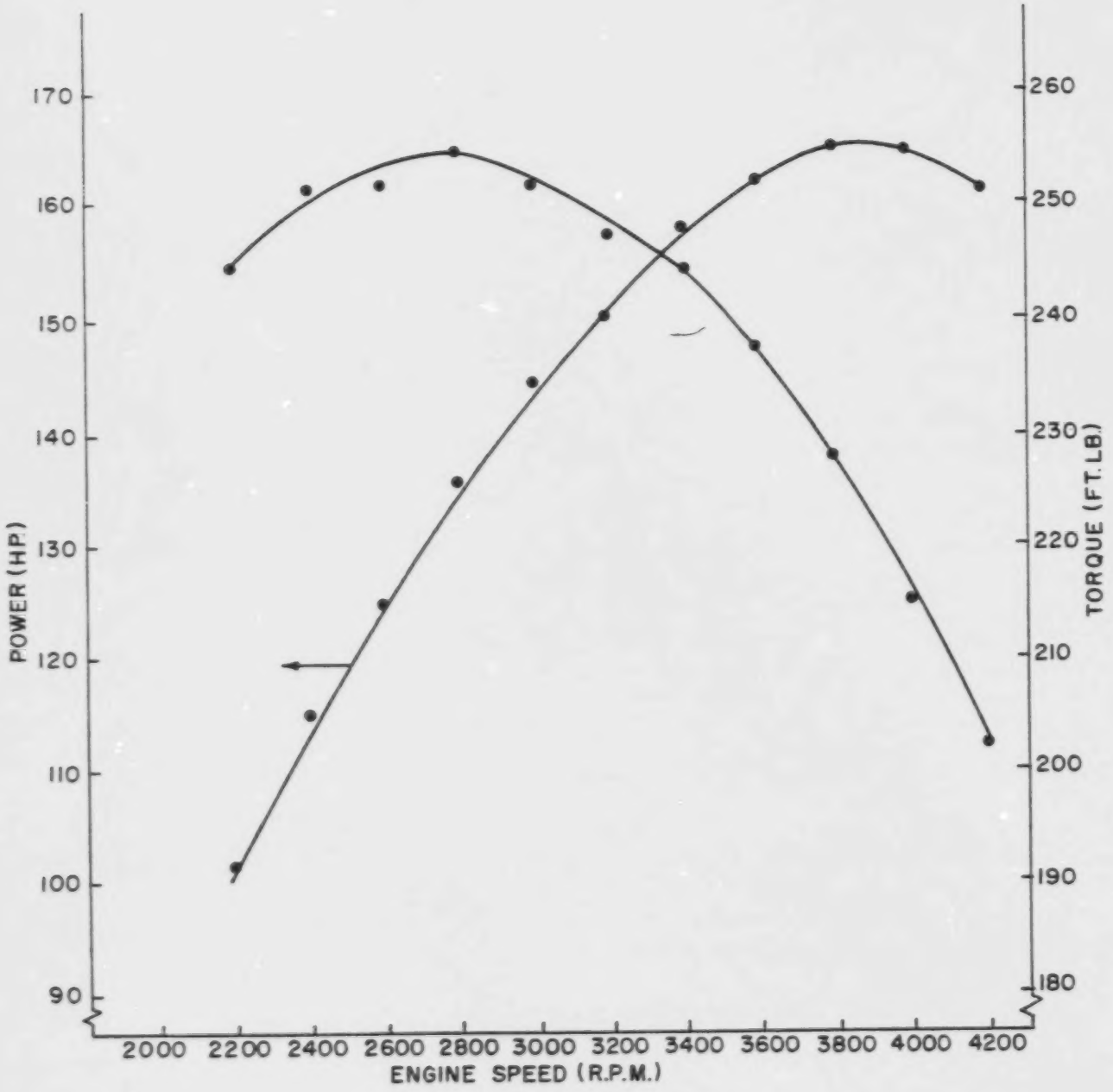


FIGURE 3 : POWER AND TORQUE CURVE OF OEM EQUIPPED 350 CID ENGINE (No accessories except waterpump and alternator)

FIGURE 4

FIXTURE FOR MEASUREMENT OF VALVE RECESS

FIGURE 3

ACTUAL VALVE RECESS

350 CID V8

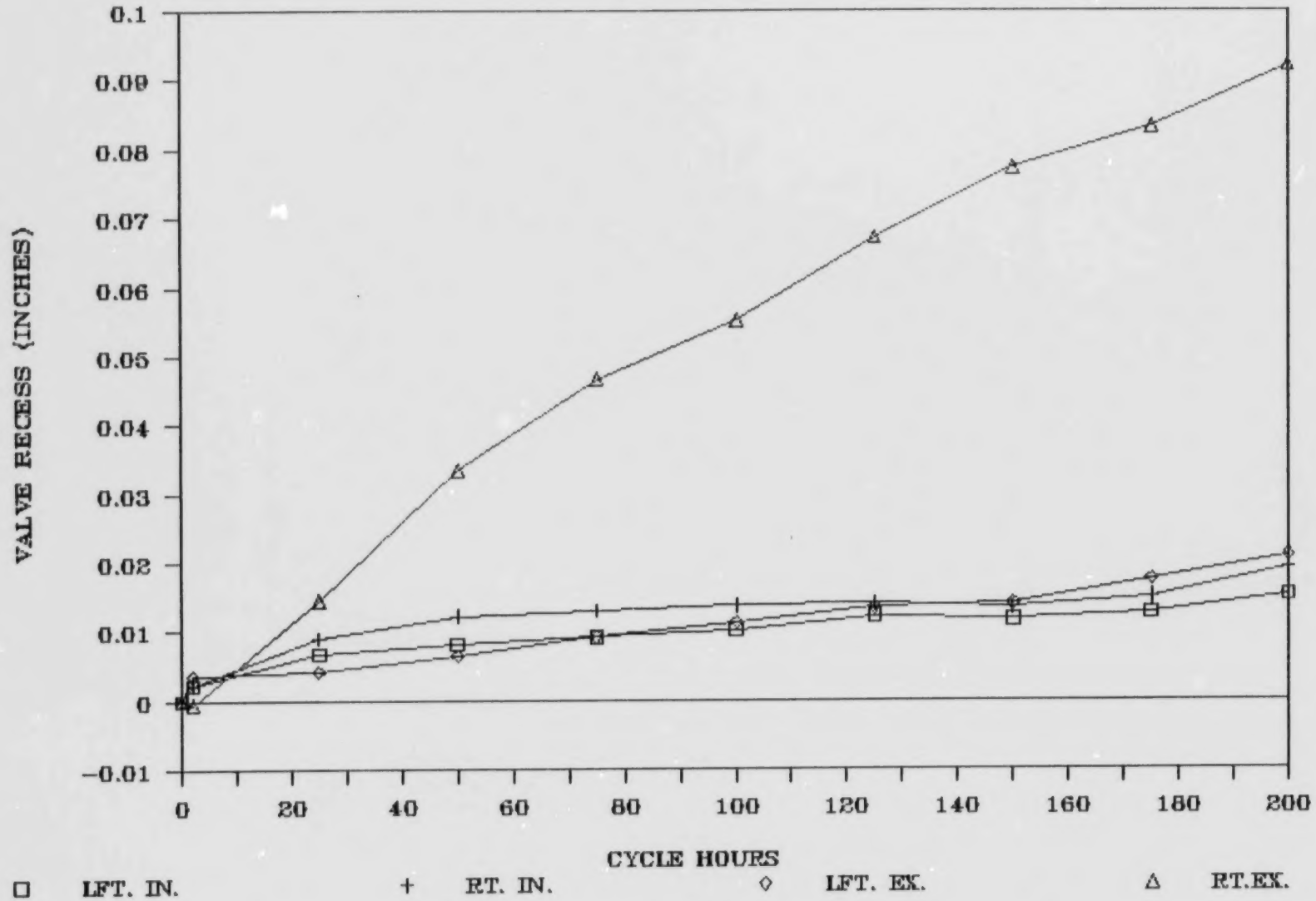
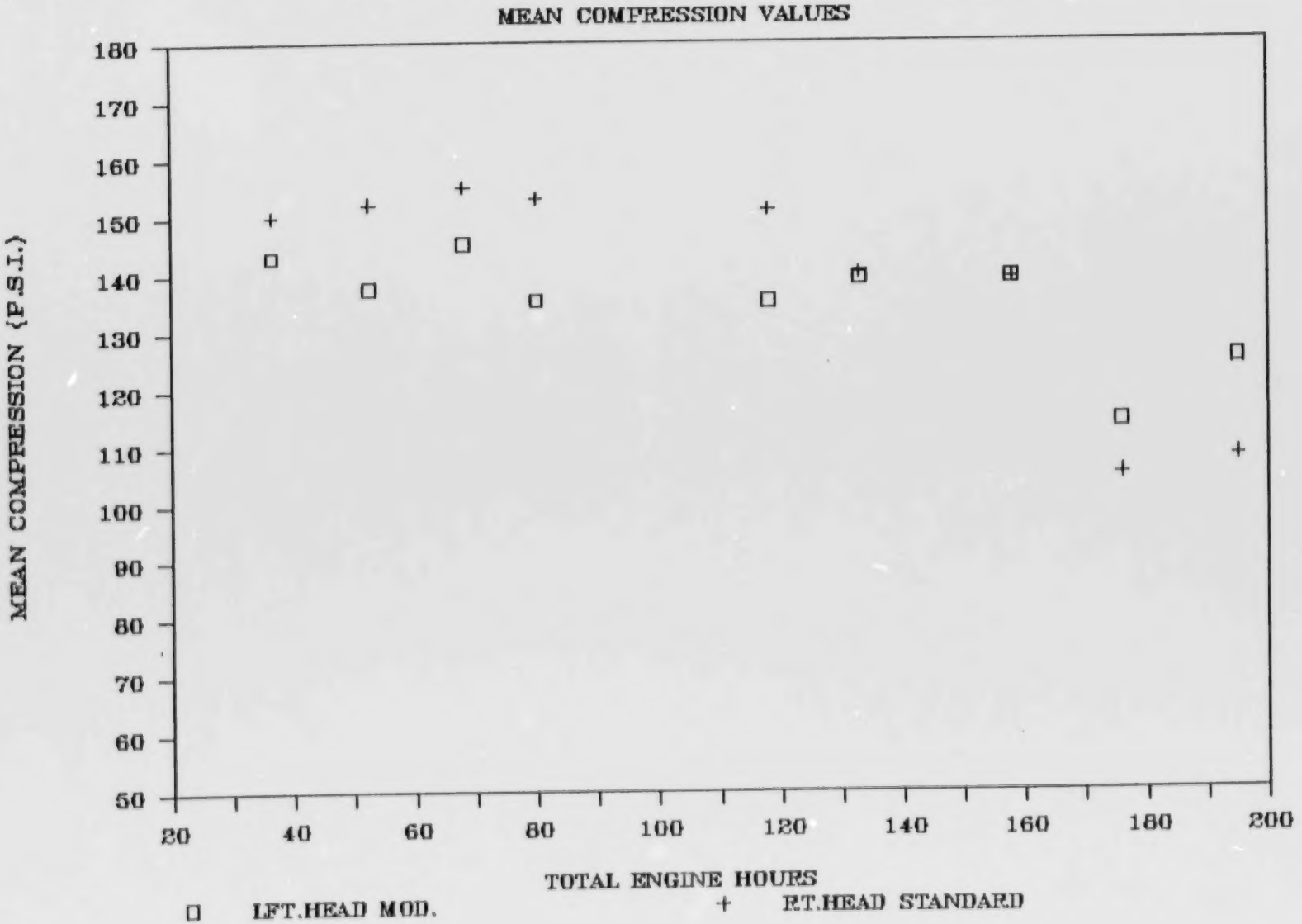


FIGURE 6

350 CID COMPRESSION DATA



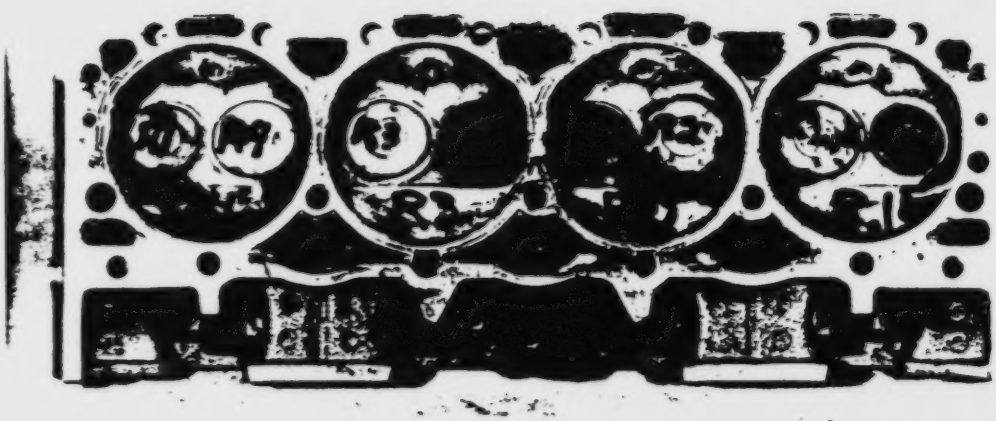


FIGURE 7

COMBUSTION CHAMBERS WITH
VALVES INSTALLED, STANDARD
GASOLINE HEAD (TS1)

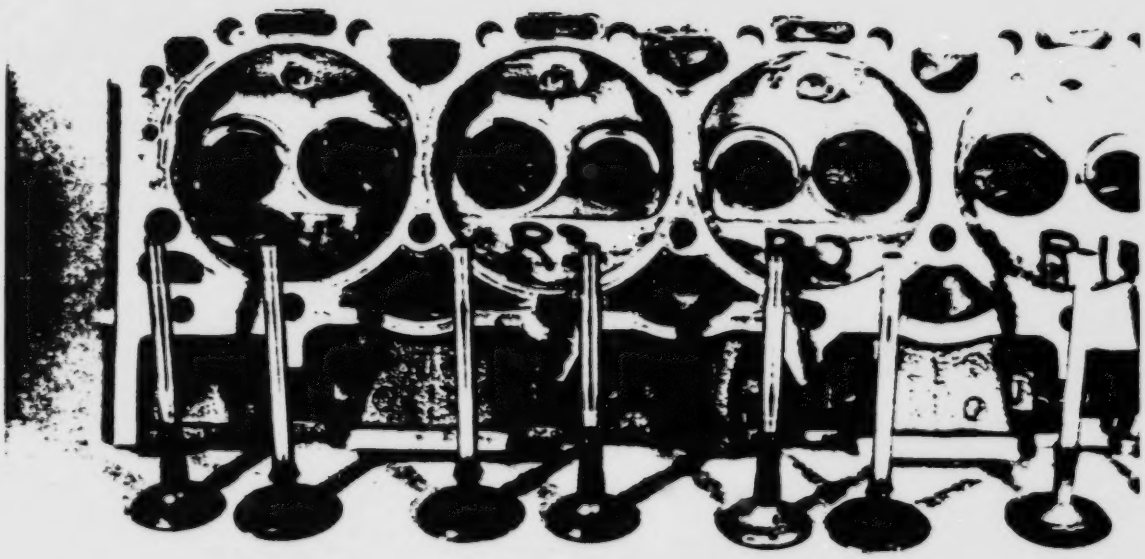


FIGURE 8

COMBUSTION CHAMBERS WITH VALVES REMOVED, STANDARD GASOLINE HEAD (TS).

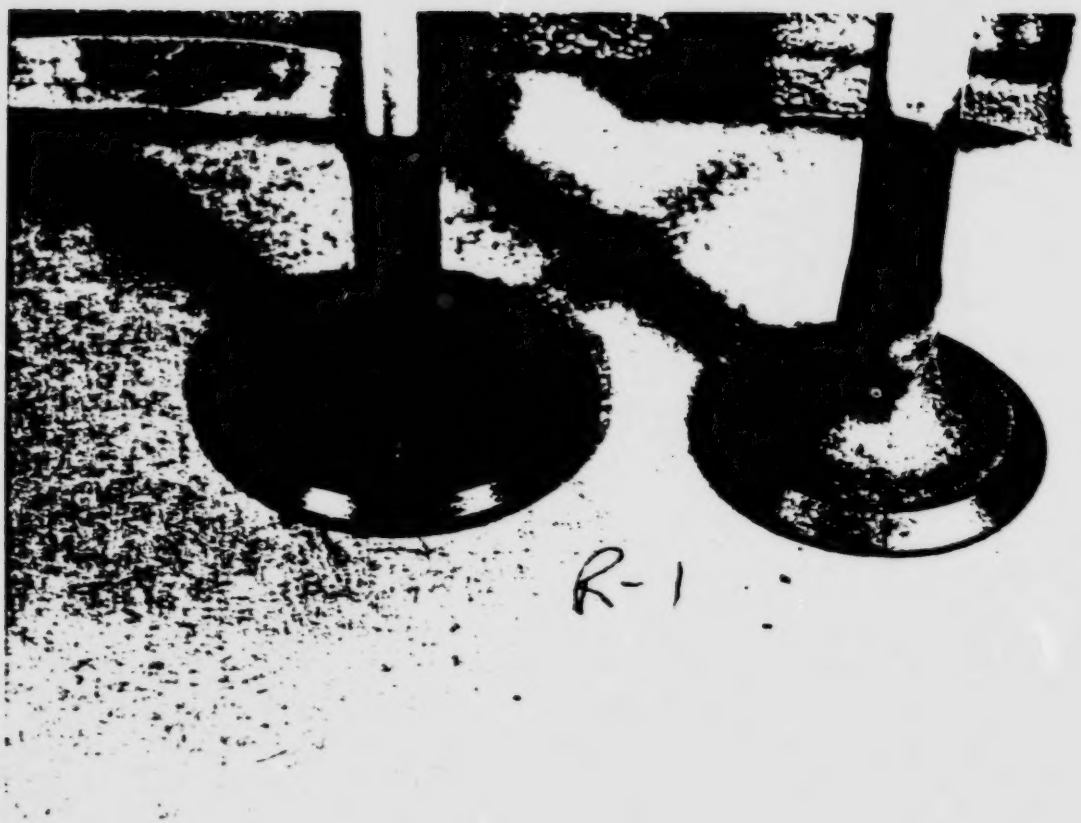


FIGURE 9

CLOSE-UP OF INTAKE AND
EXHAUST VALVE, STANDARD HEAD (TS1)

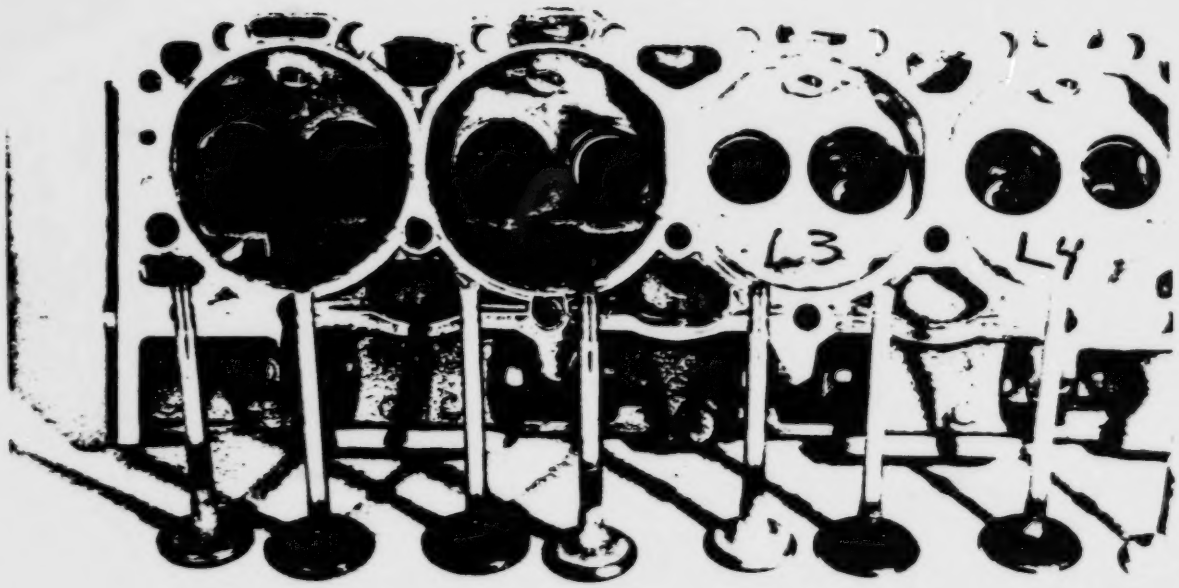


FIGURE 10

COMBUSTION CHAMBERS WITH
VALVES REMOVED, MODIFIED HEAD (TSI

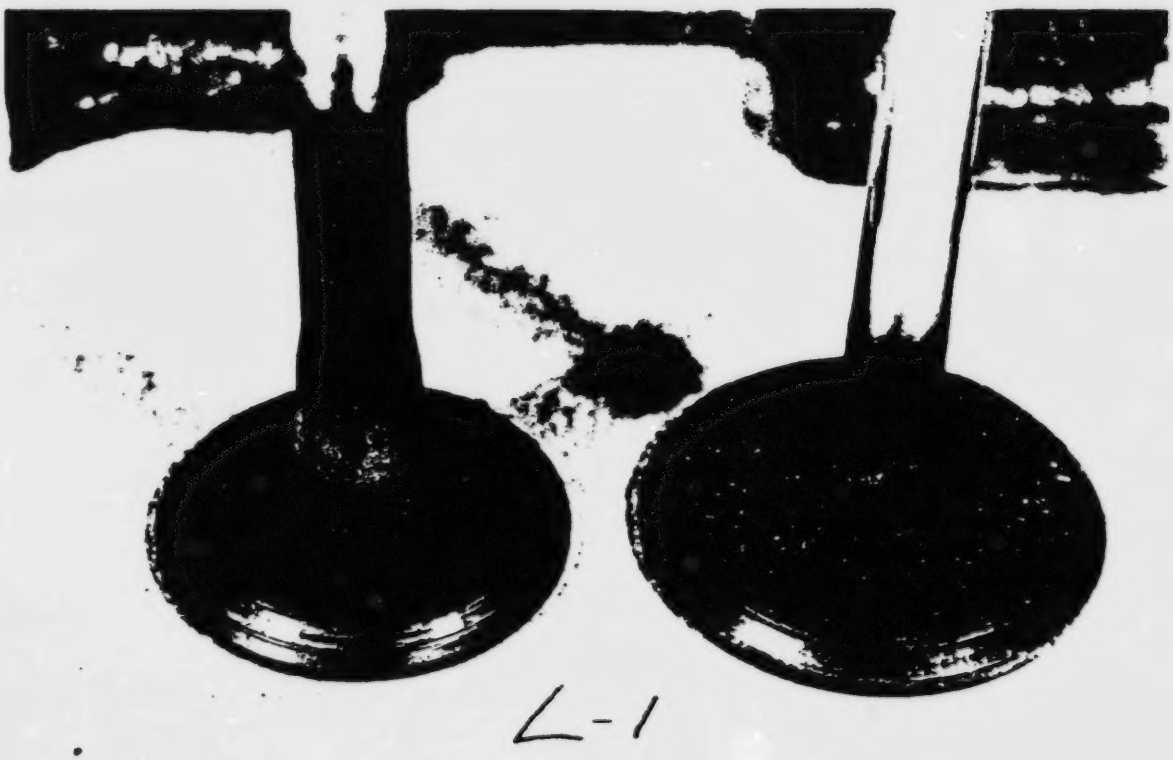


FIGURE 11

CLOSE-UP OF INTAKE AND
EXHAUST VALVE, MODIFIED HEAD (TS1)

FIGURE 12

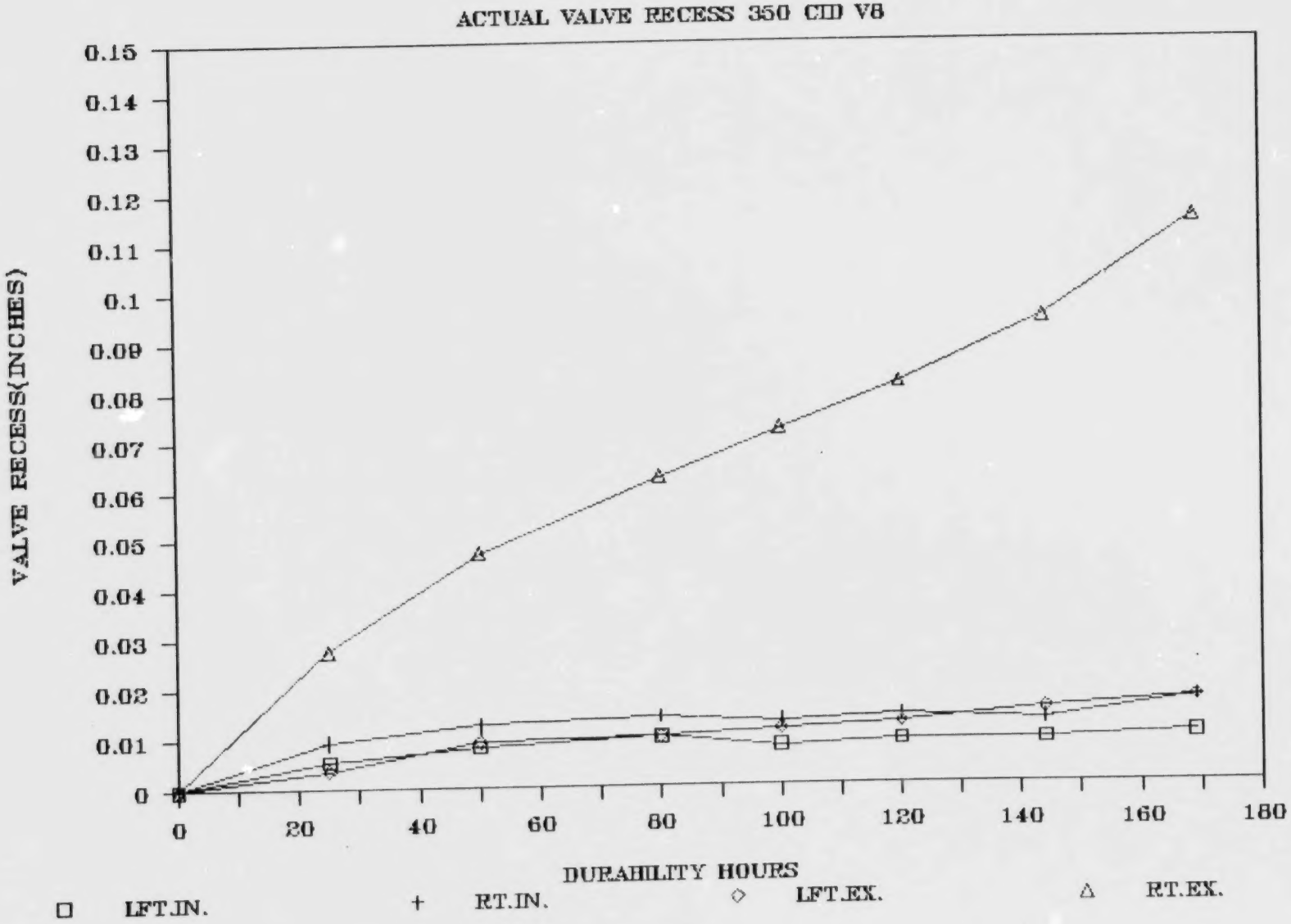
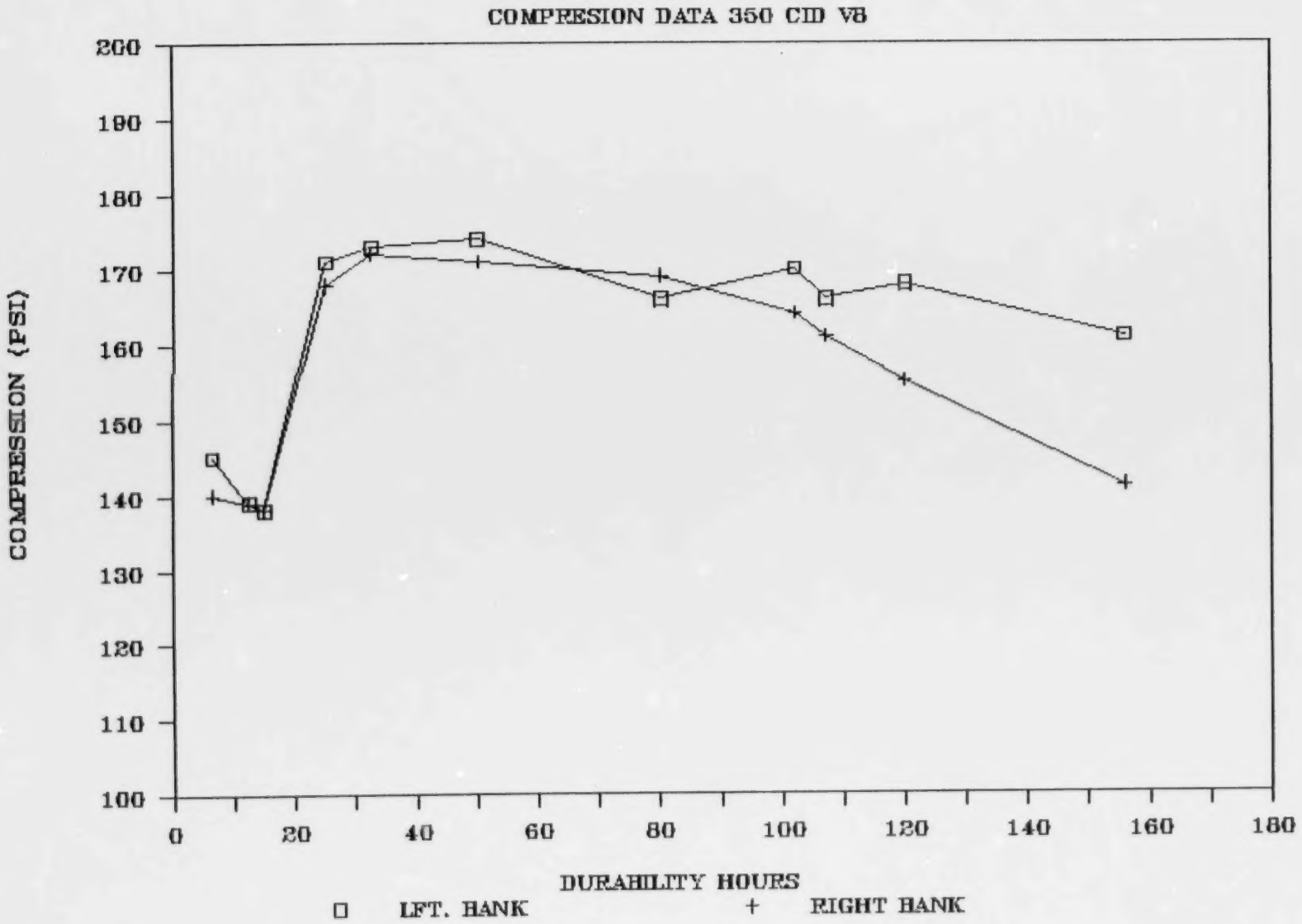

ACTUAL VALVE RECESS 350 CID V8
VALVE RECESS(INCHES)
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
180
DURABILITY HOURS
□ LFT.IN.
+ RT.IN.
◇ LFT.EX.
△ RT.EX.

FIGURE 13


COMPRESION DATA 350 CID V8
COMPRESSION (PSI)
200
190
180
170
160
150
140
130
120
110
100
0
20
40
60
80
100
120
140
160
180
DURABILITY HOURS
LFT. BANK
RIGHT BANK

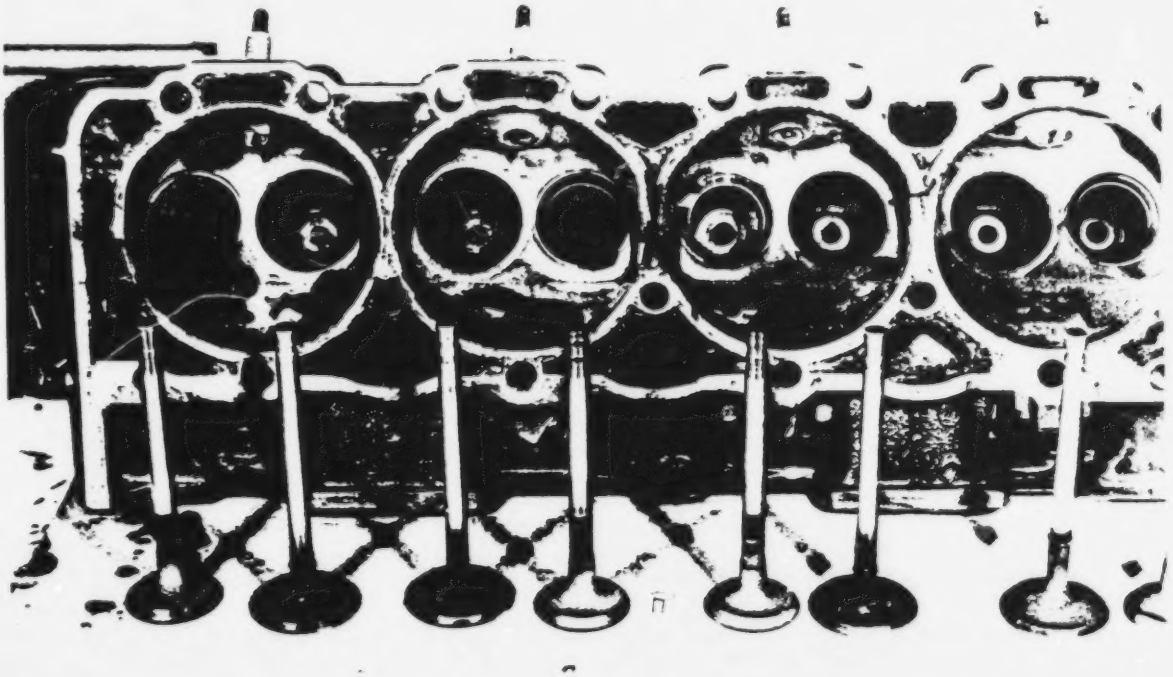


FIGURE 14

COMBUSTION CHAMBERS WITH
VALVES REMOVED. STANDARD
GASOLINE HEAD (TS2)

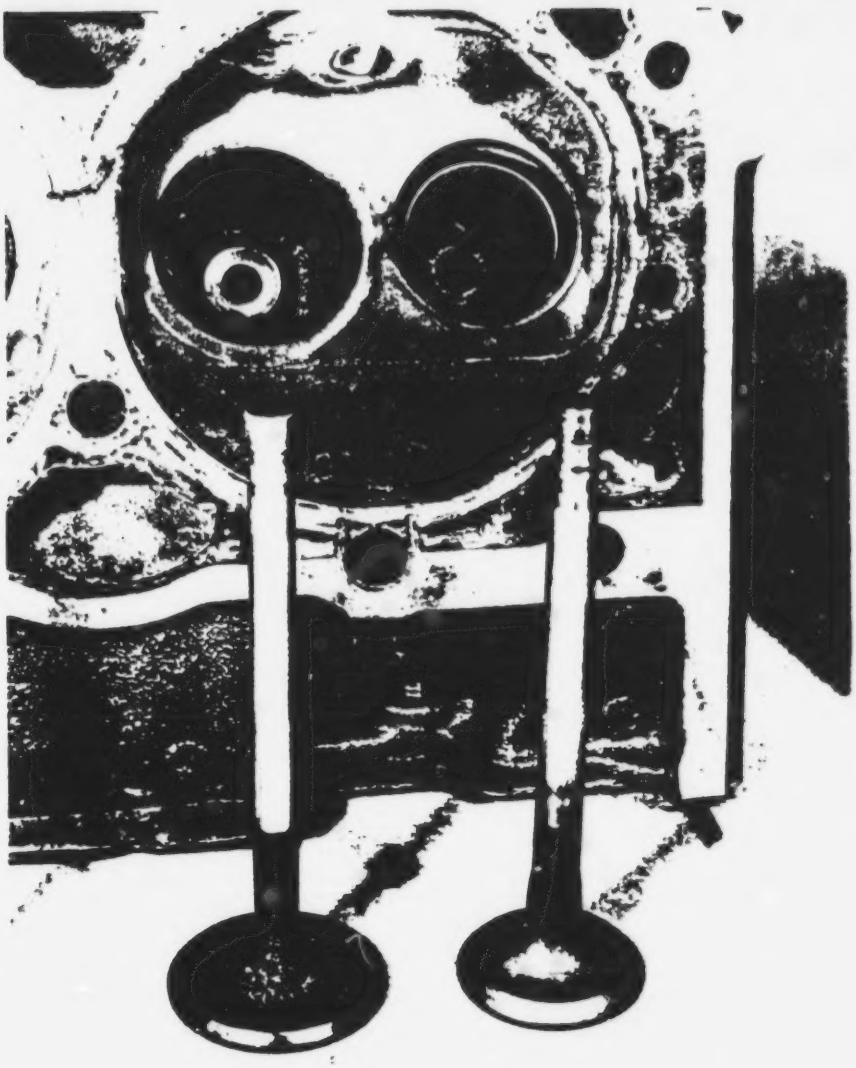


FIGURE 18

CLOSE-UP OF INTAKE & EXHAUST VALVE
& VALVE SEATS, STANDARD GASOLINE HEAD "TSD"

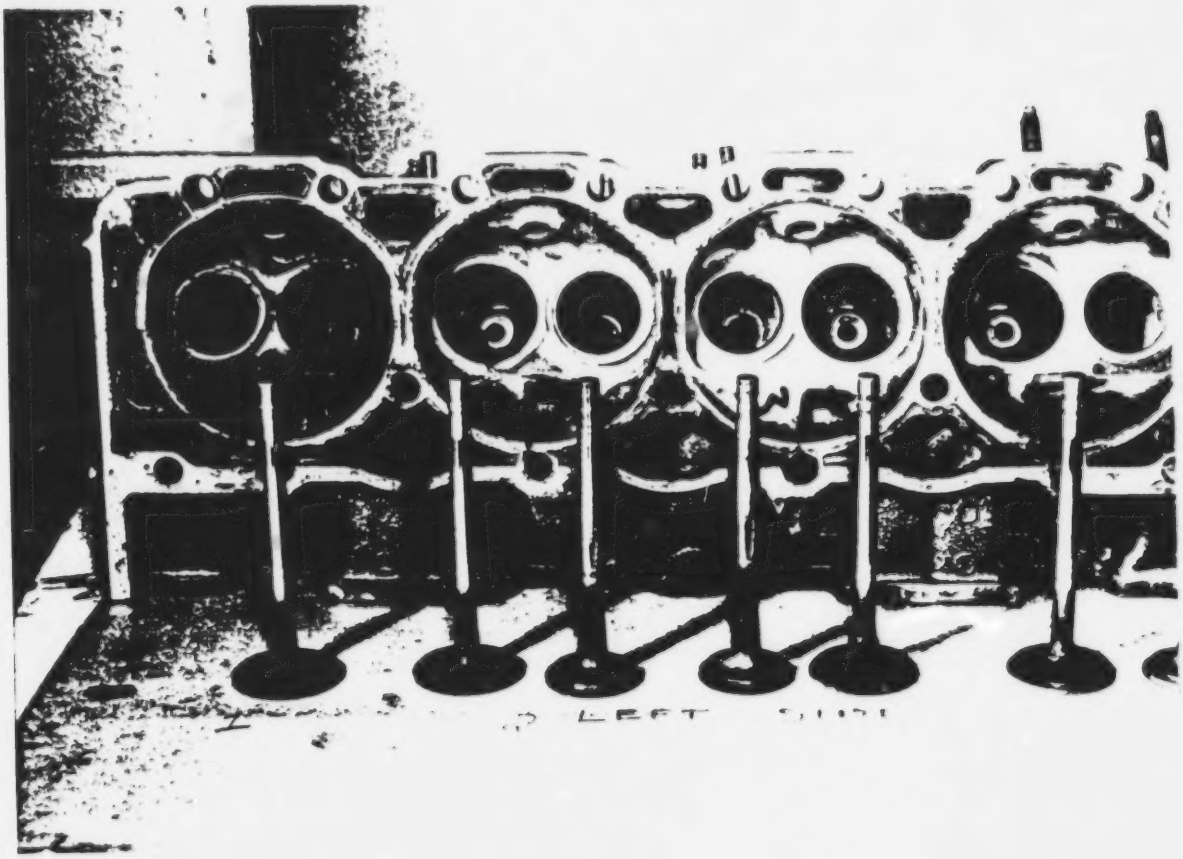


FIGURE 16

COMBUSTION CHAMBERS WITH VALVES.
MODIFIED HEAD (TS2)

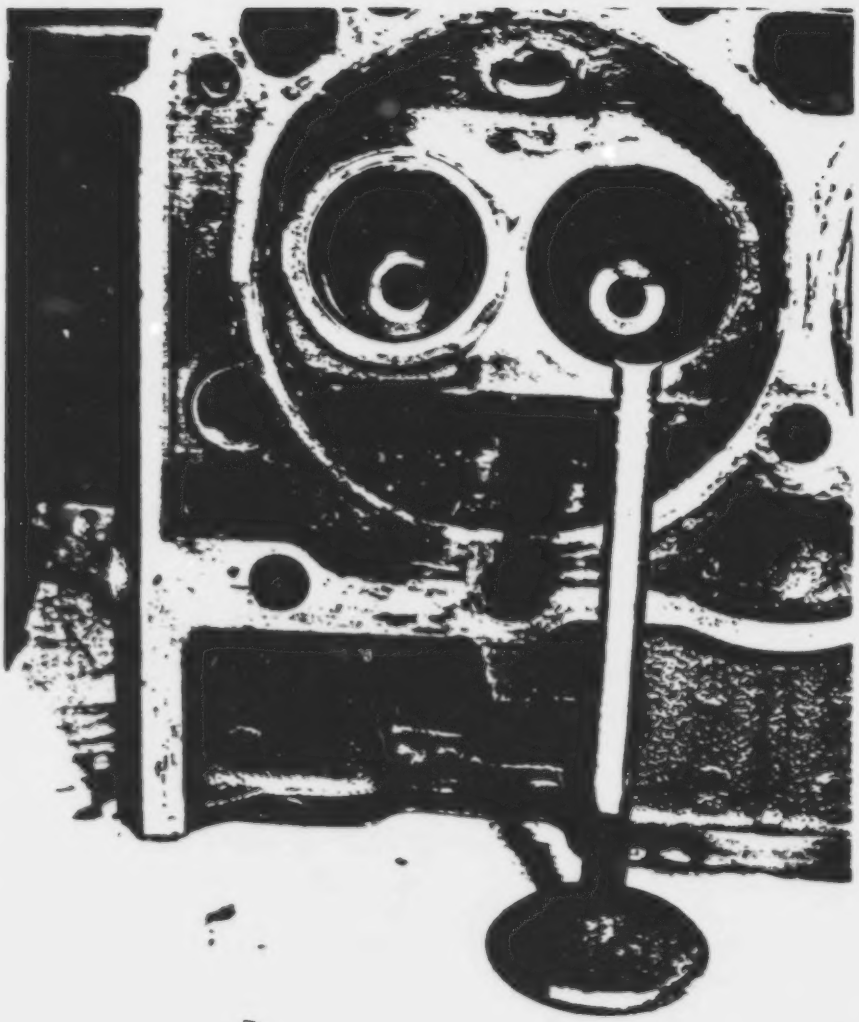


FIGURE 17

CLOSE-UP OF INTAKE VALVE
& VALVE SEATS, MODIFIED HEAD
(TS2)

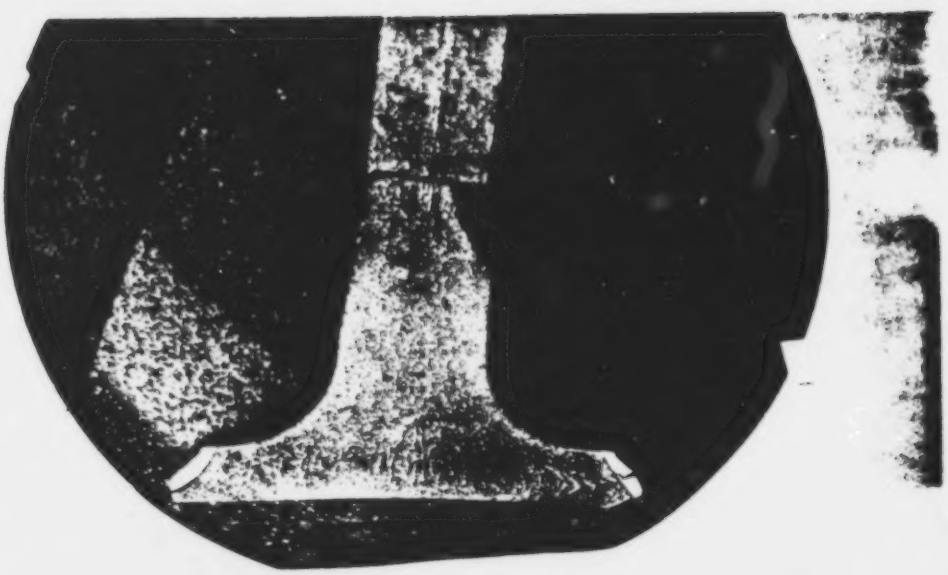


FIGURE 18

CROSS SECTION OF EXHAUST VALVE

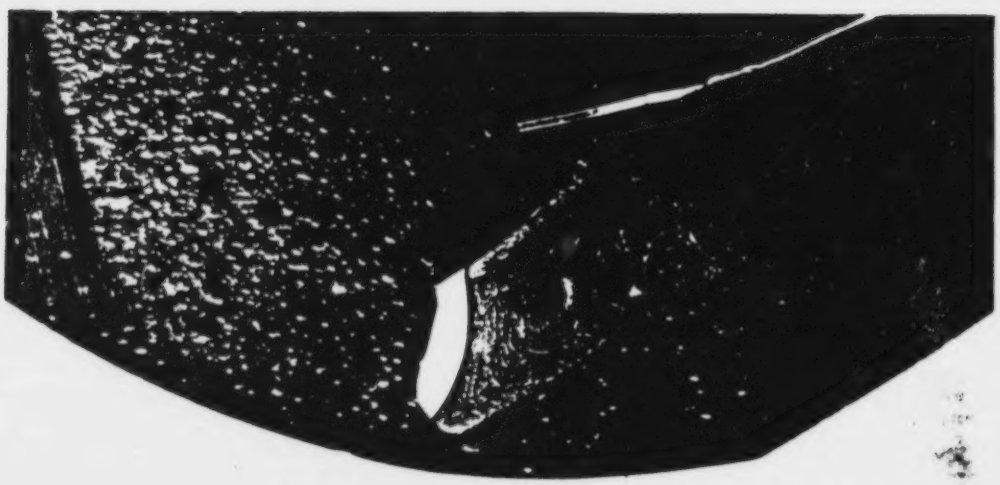


FIGURE 19

WEAR PATTERN OF EXHAUST VALVES
WITH SEAT INSERTS

APPENDIX A

CNG
FUEL SYSTEMS

INSTALLATION INSTRUCTIONS

INSTALLATION INSTRUCTIONS

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ACCEPTANCE TEST AND CONVERSION PROCEDURE

COMPONENT LOCATION

INSTALLATION

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APPENDIX

INSTALLATION INSTRUCTIONS

INTRODUCTION

All installation of compressed natural gas fuel systems and storage cylinders on highway vehicles must comply with your local and municipal by-laws.

This manual provides the necessary information for the installation of CNG Fuel Systems' Natural Gas Conversion Kit. As the existing products are modified or new products are introduced, this manual will be revised from time to time.

Installation and maintenance must be conducted by CNG Fuel Systems' trained personnel only.

ACCEPTANCE TEST

On a used vehicle, and especially one with very high mileage registered on the odometer, it is important to initially perform the Acceptance Test, to ascertain whether or not conversion is practical based on the condition of the vehicle.

Perform visual inspection of components under the hood and note abnormal service requirements. Inspect area where storage cylinders are to be fastened for possible weakness due to rust perforation. Check suspension for capability of carrying additional load of storage cylinders.

One of the important tests to perform is the "dry" and "wet" compression test. This test will indicate if piston rings or valves are possibly in need of repair or replacement.

Other areas which should be checked and recorded during Acceptance Test are: starting circuit, charging circuit, ignition system, carburation system, for engine noise, horsepower reading, emission reading, etc.

Appendix "A" shows a sample Acceptance Test check list. It is imperative that test findings are recorded for future reference.

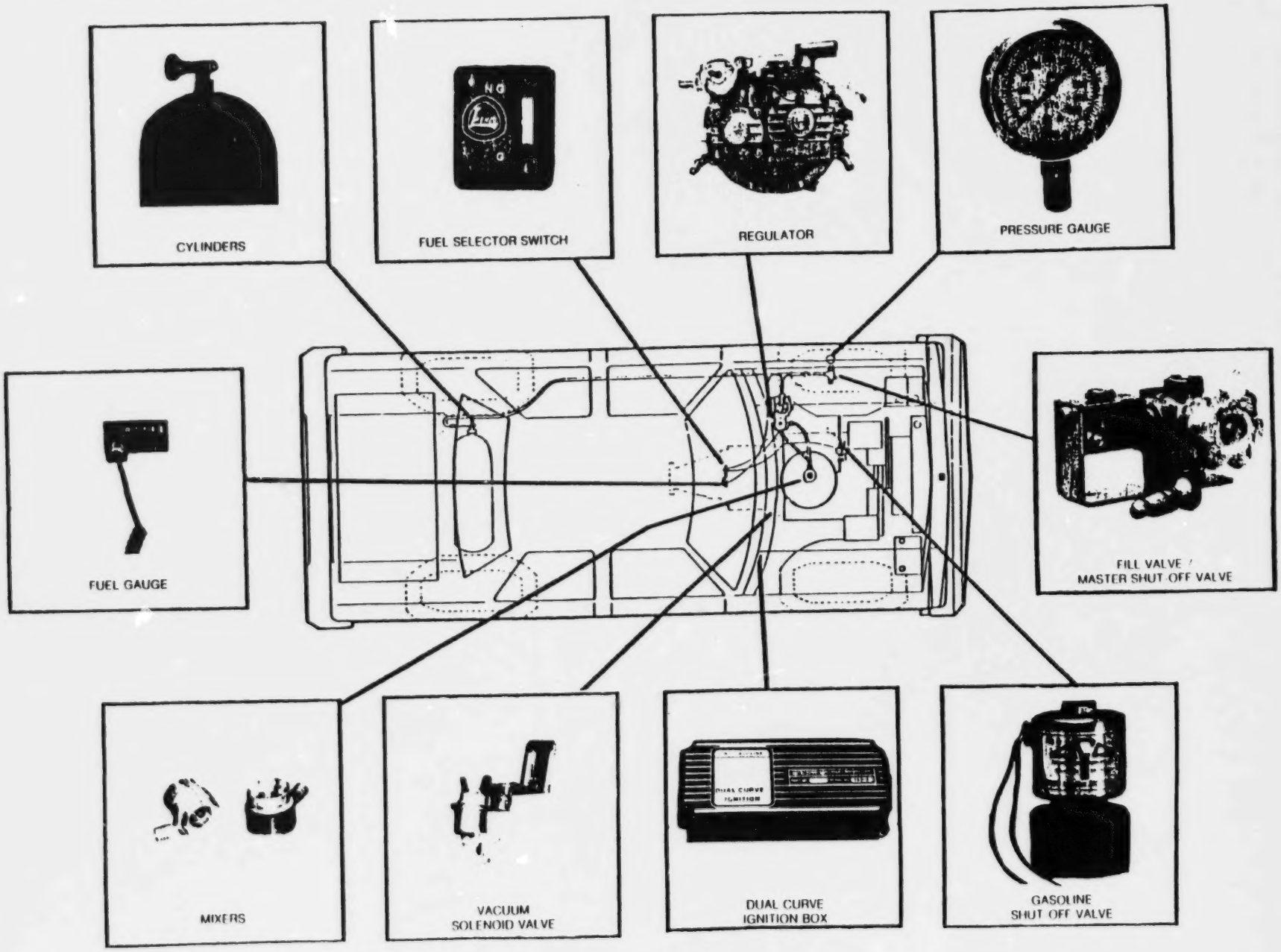
When the Acceptance Test indicates that the vehicle is satisfactory for conversion, commence the examination for available spaces, to determine where the under the-hood-components, lines and storage cylinders should be installed.

The criteria for a good installation are: (a) low pressure line from regulator to the mixer to be short as possible and without sharp bends; (b) other under-the-hood components to be visible, accessible and mounted in a close proximity to each other; (c) if at all possible, the storage cylinder outlet to be on the same side of the vehicle as the regulator.

Determine in which direction the mixer inlet pipe must face due to interference of carburetor parts, or where the regulator could be installed due to available space. Once the positions for these two components are determined and the location of the fuel filler valve is decided, conversion may commence.

CONVERSION PROCEDURE

1. Inspect condition of the vehicle body and under carriage.
2. Test engine compression.
3. Dyno test vehicle for horsepower and exhaust emission output.
4. Check vehicle for storage cylinder location, size and amount to install.
5. Consult with customer on selector switch and dash gauge location.
6. Determine fill valve location (rear fill option).
7. Briefly explain to customer, what is involved in conversion of vehicle.
8. Advise customer the date and approximate time when the vehicle will be ready.
9. Perform conversion.
10. Leak test.
11. Dyno test on gasoline and CNG. Record reading.
12. Road test.
13. Show customer on his vehicle the CNG operation, how to start when cold and hot, and how to switch the gasoline to CNG and vice versa.



CNG CONVERSION COMPONENTS

INSTALLATION

I CYLINDER(S)

1. PREPARATION OF STEEL CYLINDER

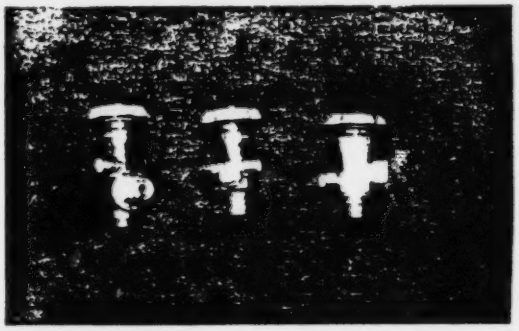
(a) Initially, thread-in the brass, cylinder shut-off valve, dry. Tighten until snug, then unscrew.

(b) Apply approved thread compound on the male thread of the valve only, then reinstall into the cylinder, finger-tight plus 3 complete turns using special tool (Fig. 1) or using Torque Wrench Torque to 150 ft. lbs. Do not use impact wrench to tighten valve.

(Initial thread-in of the valve, dry, tends to correct any minor thread irregularities, and seals better on second application).

Fig. 2 shows some of the cylinder shut-off valves that are available.

1 Tighten cylinder shut-off valve using special tool



2 Cylinder shut-off valves

2. PREPARATION OF ALUMINUM CYLINDER

External Mounting -

Aluminum cylinders have two threaded openings.

(a) Install cylinder valve (Fig. 3-B) with rubber "O" ring on the cylinder. Torque to 90 ft. lb. (122 Nm).

(b) In opposite end install right angle bushing with "O" Ring and with Fusible Cap-Type Burst Disc.

Internal Mounting -

Valves and Fittings must be bagged - see venting instructions.

(a) Install cylinder shut-off valve (Fig. 3-B) with "O" Ring on the cylinders. Torque to 90 ft. lb. (122 Nm).

(b) Remove burst disc on cylinder shut-off valve.

(c) Install vented burst disc onto cylinder shut-off valve. Install male connector and vented burst disc. Install vent tube into male connector and vent to atmosphere. Do not point end of vent tube toward exhaust system.

3-A

3-B

3-A Brass reducing bushing removed from aluminum cylinder
3-B Shut-off valve with same flange and thread as removed bushing

II INSTALLATION (cont'd)

CYLINDER(S)

(d) In other end, install right angle bushing with "O" Ring. Torque to 90 ft. lb. (122 Nm). Install vented burst disc into right angle bushing. Install male connector and vent tubing into burst disc. Vent to atmosphere making certain that the end of the vent tube is not pointed toward the exhaust system.

3. LOCATION

Some of the factors which must be considered to select a suitable cylinder location are:

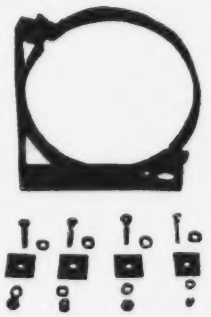
(a) Adequate space.
(b) Rigid mounting area.
(c) Accessibility of shut-off valve.
(d) Protected from road hazards.
(e) Away from exhaust system. - Minimum 4".
(f) Location where collision damage will be minimal.
(g) Shortest, protected and easiest piping route to the regulator.
(h) Do not install in restricted areas. (Check your local "Installation Code").

4. MOUNTING PROCEDURE

(a) Cylinder must be fastened in a permanent manner and secured to prevent jarring loose, slipping and rotating.

(b) Fasten mounting brackets securely with all the fasteners and reinforcing plates supplied. (Fig. 4).

(c) Use neoprene strips between bracket and cylinder.



4. Cylinder mounting bracket kit

III RELIEVING DEVICES

When steel cylinder is installed in a confined area, remove the standard, fusible and non-vented type burst disc (Fig. 5-B) from the cylinder shut-off valve and install fusible and vented type. (Fig. 5-A).

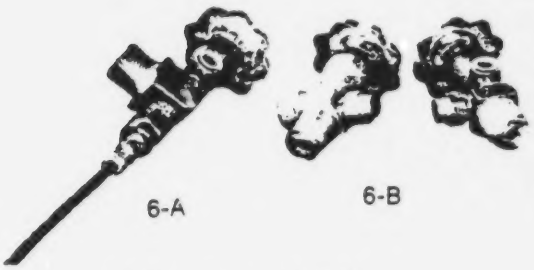
Torque to 30 ft. lb. (41 Nm).

Attach steel tube to the vented type burst disc and ventilate directly to the atmosphere. (Fig. 6-A).

Make certain that the end of the vent tube is not pointed toward the exhaust system.

5-A 5-B

5-A Fusible, vented type burst disc
5-B Fusible, non-vented type burst disc



6-A 6-B

6-A. Shut-off valve with fusible, vented type burst disc with steel tube attached.
6-B. Shut-off valve with fusible, non-vented type burst disc attached.

IV VAPOUR SEALING

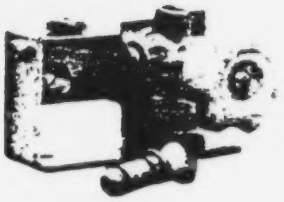
On cylinder installation in a confined area - in case of a possible CNG leak from cylinder, all attachments on the cylinder opening, such as shut-off valve, fittings, burst disc, lines, etc. must be bagged and vented directly to the atmosphere.

V FILL VALVE (Fig. 7)

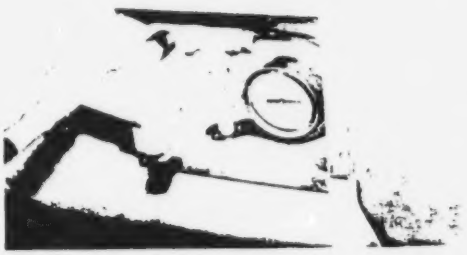
Method of fuelling will determine where the fill valve should be located.

(a) For "quick-fill" - under the hood is the ideal location for a fill valve. At this location the fill valve will be protected from weather and road splash.

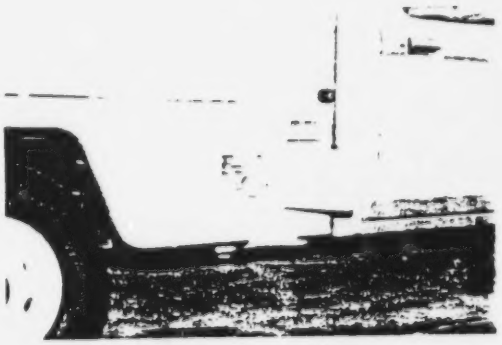
(b) For "slow-fill" - front grille, sides of body or rear fenders are locations commonly selected. If fill-valve, pressure gauge and master shut-off valve cannot be located in an area which is protected from road splash, enclose them in a weatherproof box. (Figs. 8 and 9).



7 Fill Valve



8 Slow fill at side of body



9 Fill valve at side of body in weather proof box

INSTALLATION:

1. Fill valve mounting bracket must be fastened on a rigid metal surface. Fill valve must be accessible for refuelling.

2. Fill valve should be located away from electrical source and direct heat.

VI PRESSURE GAUGE (Fig. 10)

1. Do not install in the passenger compartment. Install downstream from master shut-off valve, and near the fuel fill valve.
2. Install away from direct heat and electrical equipment.

10. Pressure gauge (glycerene filled)

VII REGULATOR (Fig. 11)

(see Low Pressure System Appendix "D")

Mount regulator -

(a) in an upright position, with the top inclined 30° towards the centre of vehicle.

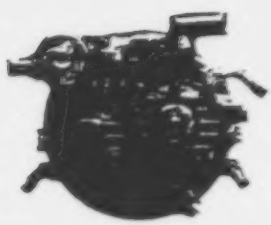
(b) with diaphragm parallel to the length of the vehicle.

(c) with outlet port below mixer inlet.

(d) with solenoids and adjustment screws accessible.

(e) as close as possible to the mixer.

(f) with mounting bracket fastened securely to the rigid part of the vehicle.



11 Regulator

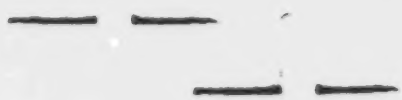
VIII REGULATOR TEMPERATURE CONTROL

To maintain constant temperature at the regulator, two methods of temperature control are used:

(A) Using engine coolant.

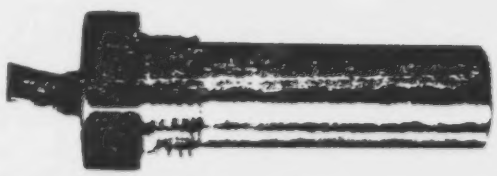
(B) Using electric heat probe.

(A) Engine coolant heating - tap into heater hoses by installing connectors. (Fig. 12).
Connect 3/8" water hoses from heater hose connectors to regulator water connections. (See Appendix "E").



12. Heater hose "T" s

(B) Where engine coolant is not available - use electric heating. Remove water hose connectors on the regulator. Insert electric probe (Fig. 13), fill void with anti-freeze, then plug the other opening. Connect probe to electric circuit, which is constantly alive while operating on CNG.



13. Electric Probe

IX PIPING AND FITTINGS

PREPARATION:

1. Route the steel tube from one component to the next to determine the length required. For a short line, include enough material for one vibration loop of approx. 2 1/2" in diameter. (6.5 cm). (Fig. 14).

2. Vibration loop is required at both ends for a longer tube which requires securing at approx. 24" intervals. (60 cm).

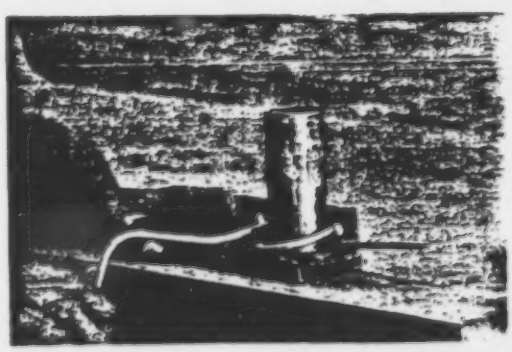
3. Leave at least 1" (2.5 cm) of straight tube at the ends of each fitting, before bending.

4. Ends of the tube are to be cut at right angle and if edges are rough, file them smooth.

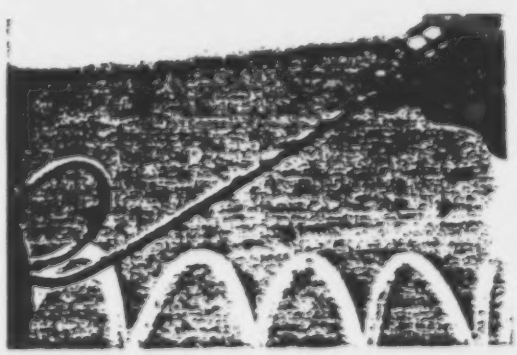
5. Do not mark, scratch or twist the tubing.

6. Deburr ends of tube with deburring tool, ensuring that the tool does not leave the wall of the tube too thin. (Fig. 15).

7. Use compressed air to clear the tube of chips and filings.



14. Forming vibration loop with special jig

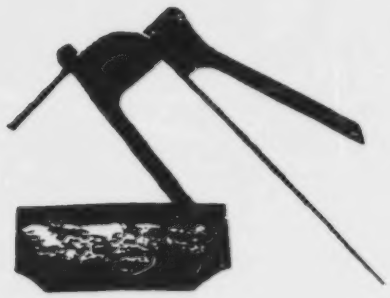


15. Deburring end of tube with a 1/4 drill bit

INSTALLATION:

1. Each fitting manufacturer has its own recommendations for fitting installation. As an example, Appendix "C" is the instruction sheets of one manufacturer's installation procedures on their fittings.

2. Use a proper bending tool to bend tube. Do not flatten tubing by bending to an acute angle which will cause excessive stress to the tubing as well as restriction to the flow of CNG. (Fig. 16).



16. Bending tube with bending tool

3. Route tubing well away from moving parts and exhaust system. Minimum 3"-5".

4. Line passing through a panel must be protected by a grommet or similar device.

5. Position fuel line so that there is reasonable protection from impact or collision, and shield if necessary.

6. Tube must be securely fastened or supported at intervals not more than 24". (60 cm). (Fig. 17 shows clip used in fastening tube).

17. Clip to fasten tubing.

7. Do not route tubing in a drive shaft tunnel.

8. Do not route tubing in the passenger compartment.

X POWER VALVE (Fig. 18)

1. Install the valve in the low pressure line and as close as possible to the mixer.

2. Make certain that the adjusting screw is accessible. (See power valve adjusting procedure).

18. Power valve

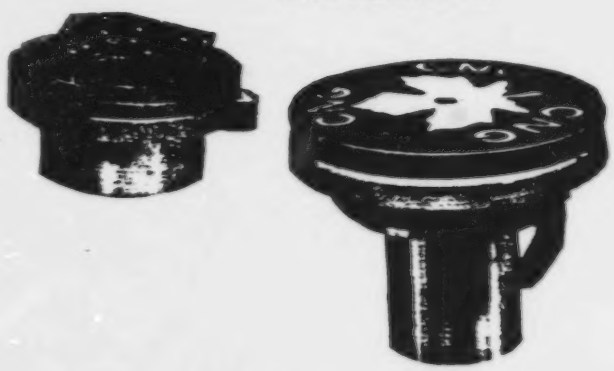
Note: Due to variation in power valve outlet and mixer inlet pipe a reducing adapter is provided.

XI MIXER

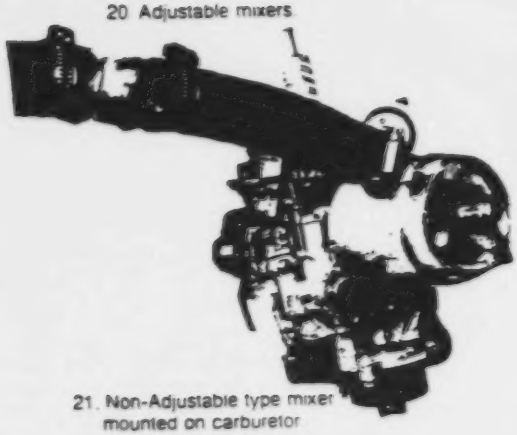
Figs. 19 and 20 show some of the variety of mixers available.

-Fig. 21 shows a mixer mounted on top of a carburetor.

19. Non-adjustable mixers



20 Adjustable mixers



21. Non-Adjustable type mixer mounted on carburetor

XII GASOLINE SHUT-OFF VALVE (Fig. 22)

1. Install between fuel pump and carburetor, as low as possible to provide clear path to ground in case of a leak.
2. Install away from direct heat.
3. Use ferrule type fitting for fuel connection.
4. Do not use clamped-on rubber hose as connector exception being on some imported engines.

XIII VACUUM SOLENOID (Fig. 23)

1. On vehicle equipped with vacuum controlled air cleaner thermal valve - while operating on CNG, the shutter in the air cleaner air inlet horn must be fully opened at all times for cold air regardless of the ambient temperature, to maintain the proper air-fuel ratio.
   Vacuum solenoid is to be installed between the thermal valve and heat sensor. (See Appendix "E" for installation schematic drawing and for wiring diagram, Appendix "F").

23 Vacuum solenoid

2. On vehicles equipped with adjustable venturi type mixer with air valve, the vacuum solenoid is to be installed so that the air valve is open on gasoline mode only.

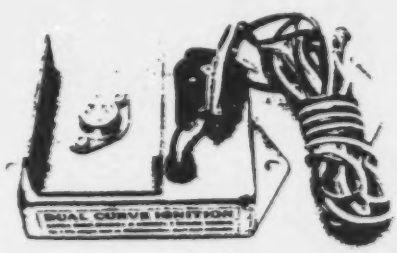
   See Appendix "G" for vacuum line hook-up and wiring diagram.

XIV DUAL CURVE IGNITION (Fig. 24 shows different types of Dual Curve Ignition Control Units).

24 -A Universal Dual Curve Ignition control unit

"A" Universal Control Unit

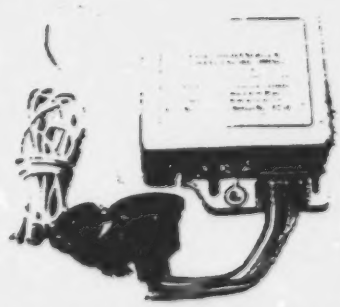
1. Install in the engine compartment.
2. Install away from direct heat.
3. Install the unit in an upright position (face-plate visible).



24 -B Direct replacement control unit

"B" & "C" Direct Replacement Control Units Exchange with original ignition module. Use the installation instruction sheets, which are included in the control unit package, to make final check of Dual Curve Ignition installation.

Electrical Component schematic drawing is attached as Appendix "F".



24 -C Direct replacement control unit

XV FUEL SELECTOR SWITCH

Fig. 25 shows Rocker Type fuel selector switch.

INSTALLATION:

Select a location on the dash which is visible and accessible to the operator and preferably on the opposite side of the ignition key.

25 Rocker type fuel selector switch

B On Rocker Type switch, priming is done automatically.

Appendix "H" is the wiring diagram of Rocker Type selector switch.

XVI FUEL GAUGE

Fig. 26 shows a dash mounted fuel gauge. To install, select a location on the dash which is visible to the operator.

26. Dash Mounted fuel gauge.

INSTALLATION TESTING

LEAK TEST

After conversion kit installation is completed, perform the leak test.

1. Close all cylinder shut-off valves.
2. Using shop compressed air, pressurize the system and use soapy water or other approved leak detectors at the joints to check for leaks. If no leak is found, then
3. Pressurize with high pressure inert gas (i.e. nitrogen) increasing pressure in stages and check for leaks. If leak is found, relieve the pressure from the system and tighten the fitting as per Appendix "C". When all leaks are stopped, then
4. Open all cylinder shut-off valves and charge the system with maximum pressure of natural gas.
5. Recheck for leaks.
6. If no leak is found, close the cylinder venting bag covering cylinder shut-off valves and fittings.

IDLE AND POWER VALVE ADJUSTMENTS

1. Set power valve screw approximately at 1/2 way.
2. Set idle screw 2 turns out from closed position.
3. Start engine on gasoline.
4. Increase engine RPM 10%.
5. Adjust timing in accordance with Dual Curve instructions supplied with the unit.
6. Switch to CNG.
7. Adjust idle screw to obtain smooth idle.
8. Adjust power valve screw by either
   (a) Utilizing tachometer:
   increase engine speed to 3,000 r.p.m. and adjust power valve screw to attain highest r.p.m.

   (b) Utilizing emission analyser:
   Increase engine speed to 3,000 r.p.m. and adjust the power valve screw to obtain .2% to .6% carbon monoxide reading.

   (c) Utilizing chassis dynomometer:
   Adjust power valve screw to highest horsepower reading in accordance with engine manufacturer's specifications.

8. Reset idle mixture to obtain:

   (a) Highest and smoothest idle r.p.m. or
   (b) emission analyzer reading of between .2% and .6% carbon monoxide reading.

9. Road test.

TROUBLESHOOTING

It is realized that only the experienced and qualified personnel will be installing natural gas conversion system and it is expected that quality work, proper procedures and safe practices will be followed.

As with any new installation, it is recommended to recheck all work done, making sure that all parts, tubing and hoses are secured, wires are connected and all original parts of the vehicle that were removed to allow for easier installation are reassembled and connected.

There are times when, in diagnosing vehicle's problems, the most obvious are overlooked. When starting up after installation, if the vehicle does not start or run smoothly, it is always a good practice, and can also be time-saving, to check the obvious areas first.

The troubleshooting chart provides guidelines to the skilled mechanics and assistance to the newcomers to natural gas conversion system in diagnosing problems that may arise.

TROUBLESHOOTING
AFTER INSTALLATION COMPLETED

SYMPTOMS	PROBABLE CAUSE	CORRECTIVE ACTION	
Engine does not turn over	Battery Terminals loose or corroded	Clean and tighten	
	Dead Battery	Charge Battery	It is recommended that, during installation, the negative battery terminal be disconnected to prevent battery draining and shorting.
	Starting Motor	Check Starting Motor	
Engine will not start on gasoline	No fuel	Refuel vehicle	
	Changeover switch in wrong position	Move switch to correct position	Two types of switches: Rocker Switch to "G" Rotary Switch to "Gasoline"
	Gasoline Solenoid	Check Solenoid action	Reference #C1 (TS-2)
	Fuse	Replace Fuse	Located in red wire from switch to fusebox.
	Changeover Switch	Check for faulty switch	Reference #C6 (TS-2)
	Coil Connections	Secure connections	Check wiring diagram supplied in dual curve kit, or CNG Installation Manual
	Dual Curve	Check connector plugs are secure on dual curve	Reference #C2 (TS-2)
	Loose connections	Check and secure all connections	
	Micro Switch	Check Continuity	Reference #C5
Engine runs on gasoline but not on CNG	No fuel	Refuel vehicle	
	Changeover Switch in wrong position	Move switch to correct position	Two types of switches: Rocker Switch to "B" Rotary Switch to "CNG"
	1/4 Turn Master Shut-Off Valve	Open Valve	
	Cylinder Shut-Off Valve(s)	Open valve(s)	
	Fuse	Replace Fuse	Located in power lead to Regulator Relay
	Relay	Check Relay - (TS-1)	With test light, and while cranking engine, check for current on Relay Lug #30. If there is current at this point but no current at Lug #87, Relay is faulty.
	CNG Solenoid	Check Solenoid	Reference #C3 (TS-1)
	Run Solenoid	Check Solenoid	Reference #4 (TS-1)

TROUBLESHOOTING
AFTER INSTALLATION COMPLETED

SYMPTOMS	PROBABLE CAUSE	CORRECTIVE ACTION	
Engine runs on CNG but idling is uneven	Improper Regulator idle adjustment	Adjust idle	Follow Installation Instructions for idle adjustment when motor is running on CNG. If it is difficult to get a proper adjustment, it may be necessary to switch back to gasoline and adjust gasoline idle. Then switch back to CNG and adjust idle screw.
	Improper Carburetor air adjustment	Adjust Carburetor	
	Gasoline idle too slow	Reset gasoline idle to Manufacturer's Specs.	
	Vacuum leak	Check vacuum lines	
Engine runs on CNG but hesitates on acceleration	Cylinder Valve(s) not completely open	Open Valve(s)	
	1/4 Turn Shut-Off Valve partially closed	Open Valve	
	CNG supply line restricted	Replace line	Refer to Installation Manual on Tube Forming
	Sharp bends in hose between Regulator and Mixer	Make gradual bends in hose	
	Insufficient gas from Regulator	Improperly adjusted Run Solenoid	Reference #C8 (TS-1)
		Larger Regulator	If capacity is insufficient, use larger regulator
	Ignition System	Check wires, coil, Ignition timing	
	Incorrect Timing	Check vacuum advance	Make certain that vacuum hose is hooked up
	Dirty filter at inlet of CNG Regulator	Clean or replace	Check source of contaminant
	Low Pressure Hose too long	Shorten hose if possible	It may be necessary to relocate mixer inlet
Won't switch from Gasoline to CNG	Power Fuse	Check Fuse	When Switch is in "CNG" position, if there are no lights on Switch, check In Line Fuse in red wire to fuse box
	Changeover Switch	Check for faulty switch	Reference #C6 (TS-2)

TROUBLESHOOTING
AFTER INSTALLATION COMPLETED

SYMPTOMS	PROBABLE CAUSE	CORRECTIVE ACTION	
Engine won't start on CNG	No fuel	Refuel vehicle	
	Changeover Switch	Position Switch	
	Fuse(s)	Replace Fuse(s)	Located in power lead to regulator relay OR Fuse Box to Switch
	Cylinder Shut-Off Valve(s) closed	Open Valve(s)	
	1/4 Turn Master Shut-off Valve closed	Open Valve	
	CNG supply line restricted	Replace line	Refer to Installation Manual on Tube Forming
	Plugged Filter	Replace or Clean	Look for source of contaminant
	Relay	Check Relay (TS-1)	With test light, and while cranking engine, check for current on Relay Lug #30. If there is current at this point but no current at Lug #87, Relay is faulty.
	CNG Solenoid	Check Solenoid	Reference #C3 (TS-1)
	Run Solenoid	Check Solenoid	Reference #C4 (TS-1)
	Flooding	Adjust Regulator	Ref. #C7 Sensitivity Screw. For details, see Manual.
		If there is still flooding, then Run Solenoid - Ref. #C8 "Run Solenoid Adjustment" (TS-1)	
No Power at high speed on CNG	Mixer air gap	Increase/Decrease	Reference #C9
	Power Valve	Adjust Valve	Refer to Installation Manual
	Vacuum Solenoid	Check correct routing of vacuum lines to vacuum solenoid, to make sure thermal door in breather intake is open. To do this, suck on hoses. The one you cannot draw through goes to vacuum source.	
	Insufficient heat at Regulator	Check coolant level; check hose	
	Dirty air filter	Clean or replace	
	Ignition Timing	Adjust timing as per Dual Curve Instruction	
	Insufficient gas flow from regulator	Larger regulator required	

TROUBLESHOOTING
AFTER INSTALLATION COMPLETED

SYMPTOMS	PROBABLE CAUSE	CORRECTIVE ACTION	
CNG consumption too high	Dirty Air Filter	Clean or replace	
	Idle set too high	Adjust idle	Refer to Corrective Action for "idling is uneven on CNG"
	Power valve adjustment	Adjust	
	Leak - C.N.G.	Check for leak	Refer to Installation Manual on Tubing Connections.
	Ignition Timing	Adjust timing as per Dual Curve Instruction	
Engine stalls	Changeover Switch	Check for faulty switch	Reference #C6 (TS-2)
	Regulator idle	Adjust idle	Refer to Corrective Action for "idling is uneven on CNG"
	Mixer Air Gap	Increase/Decrease	Reference #C9
	Induced voltage pick-up wire	Check wire and secure	(TS-2)
	Air intake	Make sure air intake is clear of any interference	

TROUBLESHOOTING PROCEDURES

Reference

C1 - **Gasoline Solenoid Circuit**

To check gasoline solenoid circuit - move the changeover switch back and forth between "gasoline" and "pause". You should clearly hear the clicking action of the solenoid. If the work area is too noisy, use a test light.

If the solenoid is inoperative, then check for:

(a) incorrect wiring
(b) open fuse in red wire between switch and fusebox
(c) sticking or faulty solenoid
(d) faulty changeover switch

C2 - **Dual Curve**

Universal- (a) Check live connections from battery to Dual Curve.
(b) Check high tension lead for spark. If there is a spark, consider Dual Curve okay.
(c) If there is no spark, unplug Dual Curve and connect adapter plug which bypasses Dual Curve. If engine starts, then it is a faulty Dual Curve.

Direct Replacement- The direct replacement Dual Curve has no plug adapter. If there is no spark, unplug the Dual Curve and connect the vehicle's original box, making sure the box is grounded, to see if the engine starts. If the engine starts, then it is a faulty Dual Curve.

TROUBLESHOOTING PROCEDURES

C3 - **CNG Solenoid**
With test light and while cranking engine, check if there is current at the CNG High Pressure Solenoid lead connection to the relay - lug #87. If there is current at this point, and the CNG solenoid is inoperative, then check for:
(a) loose connections
(b) not enough current to operate CNG Solenoid, (check battery).
(c) sticking or faulty CNG Solenoid. If faulty, replace both valve and solenoid.

Reference

C4 - **Run Solenoid**
With a test light and while cranking engine, check if there is current on Lug #87 of the relay. If there is current at this point and the Run Solenoid is inoperative, then check for:
(a) loose connections
(b) not enough current to operate Run Solenoid. (Check battery)
(c) sticking or faulty Run Solenoid.

C5 - **Micro Switch**
With test light and while cranking engine, check if there is current at **both** terminals. If there is no current, check for:
(a) faulty wire
(b) stuck switch
(c) if still no current, replace switch.

C6 - **Changeover Switch**
With key on, rock switch from "gasoline" to "CNG". If there are no audible sounds from solenoids, and wiring and solenoids have been checked,-
With test light, connect to + terminal and check to see if there is current at this point.
If there is current here, connect test light to switch terminal marked "Benzina" or "Gasoline". Set switch to "G". If no current at this point, switch is faulty.
If there is current at this point, move switch to "NG" and connect test light to terminal GPL or CGN.
If current is there, the light will come on for the first few seconds and then go out if cranking is not begun. When cranking is started, the light should come back on. Then the switch is okay. If the light does not come on when cranking, first check that the induced voltage pick-up wire is connected. If the wire is okay, and high voltage is there when cranking, but the light is still not on, the switch is faulty.

C7 - **Sensitivity Screw Adjustment**
Turn sensitivity screw until it **lightly** bottoms. Turn back out one full turn. Start vehicle and rotate the screw to smooth idle.

TROUBLESHOOTING PROCEDURES

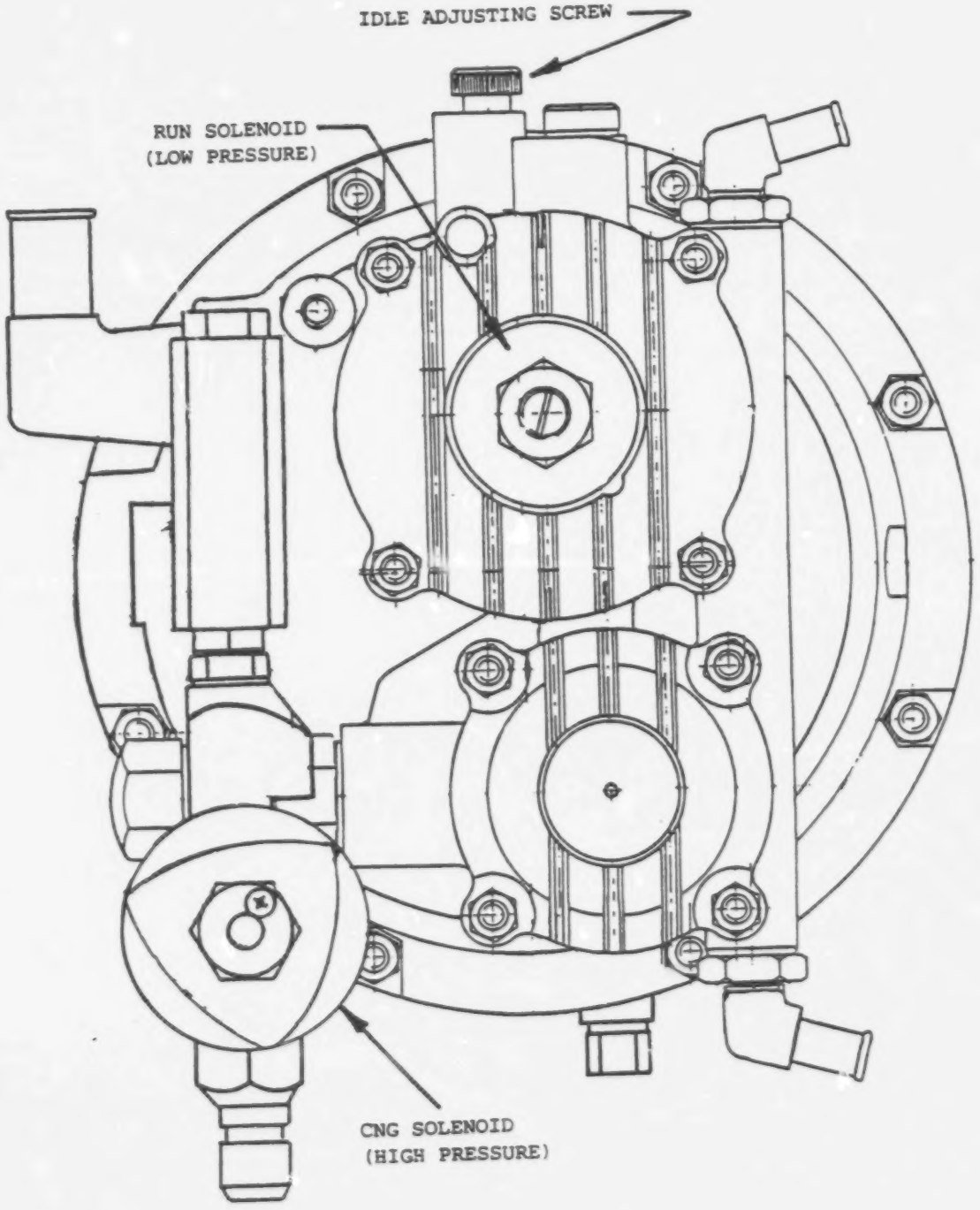
Reference

C8 - **Run Solenoid Adjustment**
Remove low pressure neck from regulator to observe adjustment procedure through the opening. Unlock Run Solenoid lock nut, insert finger in 3rd stage vent hole, press lightly on diaphram. With screw driver, adjust Run Solenoid, adjusting screw until you can just feel the tension on your finger on diaphragm. Tighten lock nut on Run Solenoid and replace low pressure neck to regulator. If this does not cure the problem, replace regulator.

C9 - **Mixer Adjustment**
Check gap first to see that it measures 100 thousandths all around. It may be necessary to adjust for more or less gap, until the power is right.
To do this, unlock the three locking screws, adjust the three adjusting screws (the ones that are springloaded) 1/4 turn at a time, to ensure the gap is even all around. Then relock the three locking screws.

TN SERIES REGULATOR

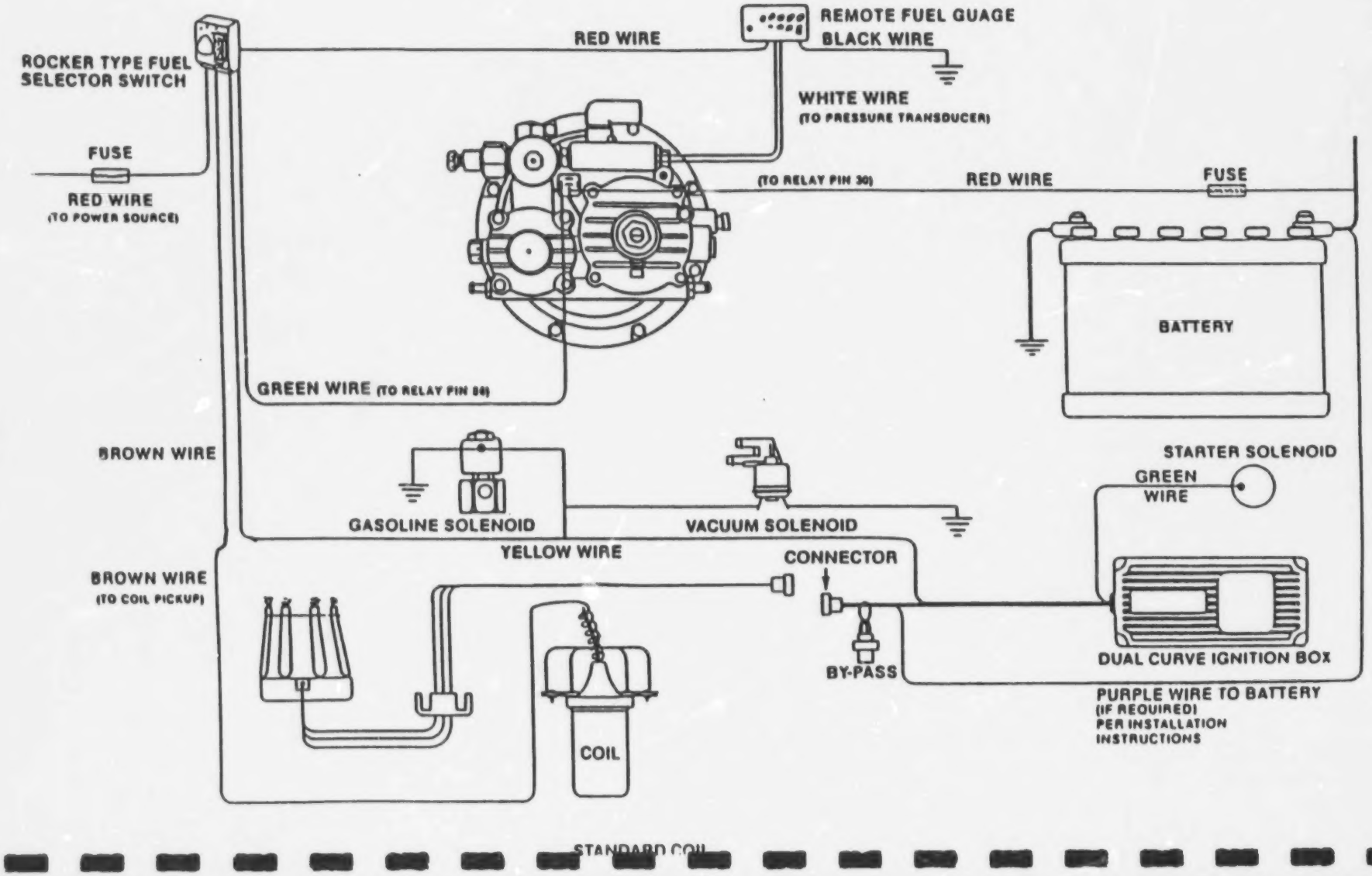
TS-1



CNG FUEL SYSTEMS

ELECTRICAL COMPONENTS

CNG FUEL SYSTEMS



APPENDIX "A"

CNG CONVERSION CHECK LIST

CUSTOMER _____ DATE _____

_____ PHONE _____

VEHICLE YR/MAKE _____

VIN NO. _____ IGNITION: STD ELECTRONIC HEI

TRANS _____ CARB _____ MILEAGE _____

UNDERHOOD INSPECTION COOLANT _____ CID/CYLS _____

BELTS _____ HOSES _____ LUBE OIL _____

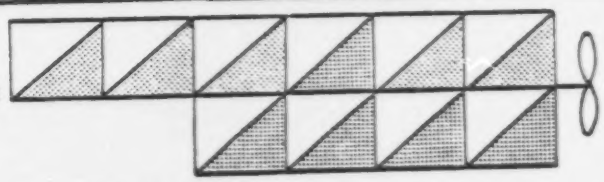
	RULE OF THUMB SPECS.	BEFORE CONVERSION ACCEPT TEST	BEFORE CONVERSION USING GASOLINE	AFTER CONVERSION USING CNG
1. CRANKING VOLTS AT BATTERY (CRANK 15 SECS)	9.6 V (MIN)			
2. CHARGING SYSTEM	REG. SETTING 14 TO 15 V			
3. PRIMARY CIRCUIT NOTE: PTS. RES. ON HEI & ELECT. DOES NOT APPLY	POINTS RESISTANCE FORD .25 V OTHER .2 V			
	DWELL			
	IDLE RPM			
4. SECONDARY CIRCUIT	PLUG SPIKES 6-12 kV			
5. TIMING BASIC (VACUUM DISCONNECTED) MECHANICAL (VACUUM DISCONNECT) TOTAL ADVANCE AT 2200 RPM (VAC. CONN.)	FACTORY SPECS. BASIC 0-10° 25/40 ADV.			

6. CARBURETION BE SURE TO WAIT FOR STABLE READINGS 10 TO 15 SECS. AFTER EACH CHANGE OF THROTTLE POSITION.	HC	CO	HC	CO	HC	CO	HC	CO
IDLE								
TRANSITION								
CRUISE								
FULL POWER								

7. COMPRESSION

CYLINDER BALANCE

GAS



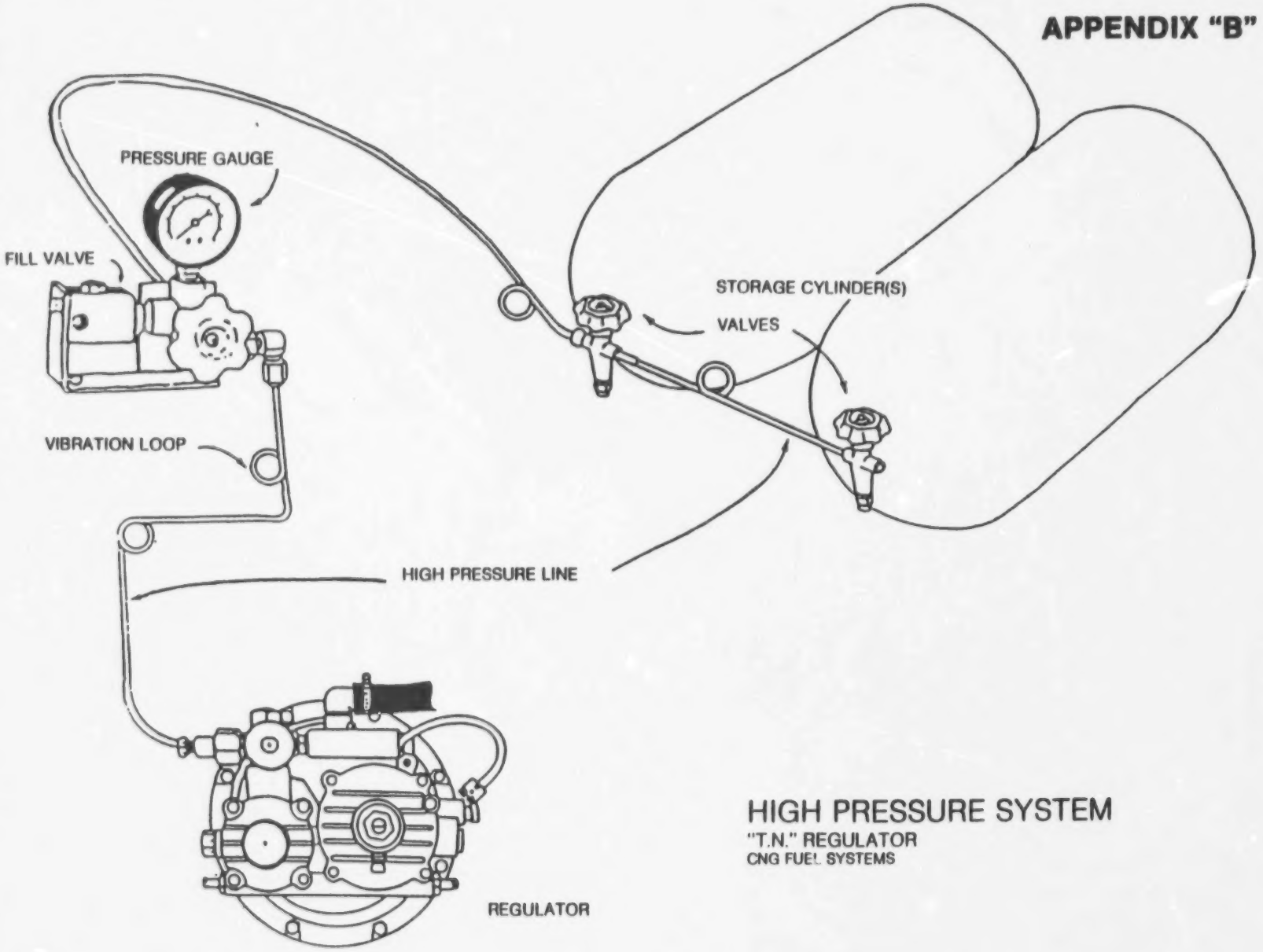
FIGURES INDICATE DROP IN RPM

8. ROAD HORSEPOWER
2500 RPM AT WIDE OPEN THROTTLE IN DIRECT DRIVE OR ONE GEAR LOWER AT 3000 RPM.

_____ RHP _____ RHP _____ RHP

REMARKS: _____

APPENDIX "B" - TN



HIGH PRESSURE SYSTEM
"T.N." REGULATOR
CNG FUEL SYSTEMS

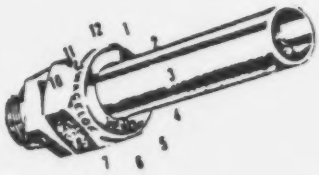
Swagelok® TUBE FITTINGS

SWAGELOK Tube Fittings come to you completely assembled, finger-tight. They are ready for immediate use. Disassembly before use can result in dirt or foreign material getting into the fitting and causing leaks.

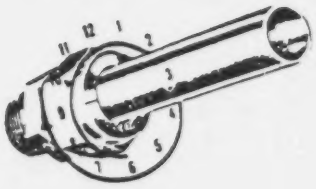
INSTALLATION INSTRUCTIONS

SWAGELOK Tube Fittings are installed in three easy steps.

STEP 1
Simply insert the tubing into the SWAGELOK tube fitting. Make sure that the tubing rests firmly on the shoulder of the fitting and that the nut is finger-tight.



STEP 2
Before tightening the SWAGELOK nut, scribe the nut at the 6:00 o'clock position.



STEP 3
Now while holding the fitting body steady with a backup wrench, tighten the nut one-and-one-quarter turns*. Watch the scribe mark, make one complete revolution and continue to the 9:00 o'clock position.

By scribing the nut yourself at the 6:00 o'clock position as it appears to you, there will be no doubt as to the starting position. When tightened 1-1/4 turns* to the 9:00 o'clock position you can easily see that the fitting has been properly installed.

For 1/16", 1/8", 3/16", 2, 3 4MM size tube fittings, only 3/4 turns from finger-tight is necessary.

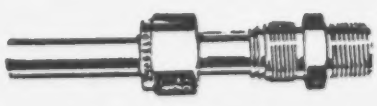
High Pressure Applications, High Safety Factor Systems

Due to the variation of tubing diameters, a common starting point is desirable. Therefore, use a wrench to snug up the nut until the tubing will not turn (by hand) in the fitting. At this point, scribe the nut and body of the fitting. Now tighten the nut one-and-one-quarter turns and the fitting is ready to hold pressures well above the working pressure of the tubing.

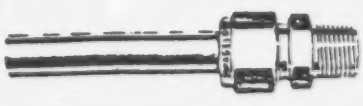
RE-TIGHTENING INSTRUCTIONS

Connections can be disconnected and re-tightened many, many times and the same reliable, leak-proof seal obtained every time the reconnection is made.

Fitting shown in disconnected position.



Tubing with pre-swaged ferrules inserted into the fitting until front ferrule seats in fitting.



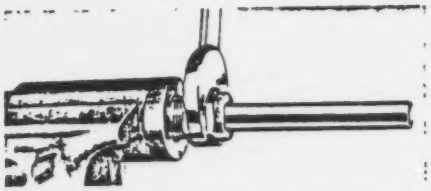
Tighten nut by hand. Rotate nut about one-quarter turn with wrench (or to original one-and-one-quarter tight position). Then snug slightly with wrench.

Swagelok® TUBE FITTINGS

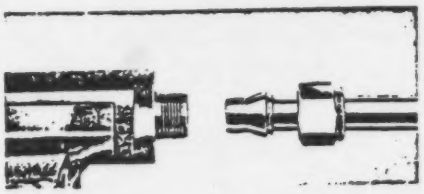
PRE-SWAGING INSTRUCTIONS

When SWAGELOK Tube Fittings are to be installed in cramped quarters or overhead where ladders must be used, it is sometimes found advantageous to use a pre-swaging tool on the tubing in an open ground area, thus pre-swaging the ferrules onto the tubing. The tubing is then removed from the pre-swaging tool and the tubing (with nut and pre-swaged ferrules) can now be attached to a fitting merely by following the *re-tightening instructions.*

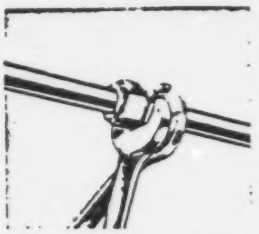
While pre-swaging tools can be used many times, they do have a finite life. After frequent use, ask your local sales and service representative to have them checked.



1. Assemble SWAGELOK nut and ferrules to pre-swaging tool. Insert tubing until it bottoms in the fitting body, and tighten nut one-and-one-quarter turns.



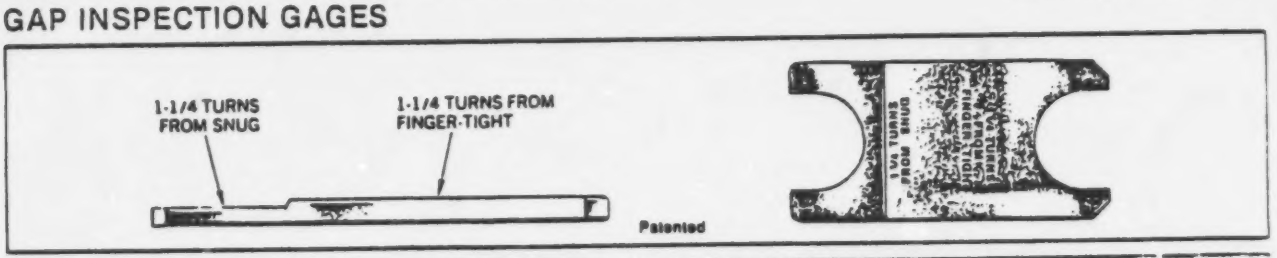
2. The nut is loosened and the tubing with pre-swaged ferrules is removed from the pre-swaging tool.



3. The connection can now be made by merely snugging up the nut as described in the *re-tightening instructions.*

Hydraulic swaging units are now available in 1/2", 5/8", 3/4" and 1" sizes.
For further information consult your local SWAGELOK Sales and Service Representative.

GAP INSPECTION GAGES



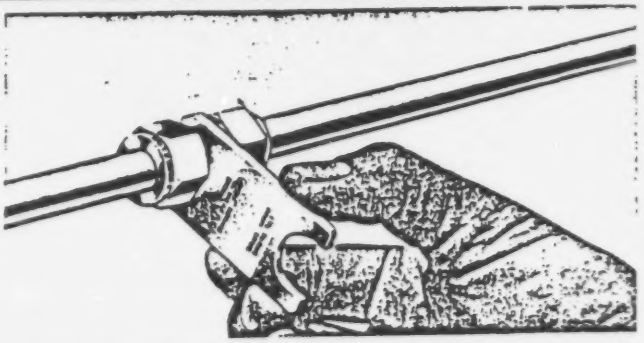
Fitting Size (Inches)	Series	Inspection Gage Part Number
¼	200	MS-IG-200
3/16	300	MS-IG-300
⅜	400	MS-IG-400
5/16	500	MS-IG-500
½	600	MS-IG-600
⅝	810	MS-IG-810
⅝	1010	MS-IG-1010
¾	1210	MS-IG-1210
⅞	1410	MS-IG-1410
1	1610	MS-IG-1610

As described on page 3, SWAGELOK Tube Fittings are made to exacting tolerances. Without such close tolerances, the interaction of the nut, two ferrules, and body would not be successful.

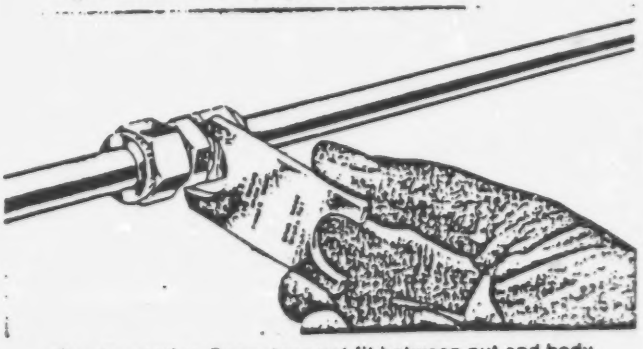
If good quality tubing is used with SWAGELOK Tube Fittings, successful connections will result if installation instructions are followed.

SWAGELOK GAP INSPECTION GAGES are designed to assure the installer or inspector that a fitting has been sufficiently pulled up. They are particularly applicable to systems where fittings are to be tightened in difficult or inaccessible locations or systems where insufficient pull-up could cause potentially dangerous or expensive consequences.

SWAGELOK GAP INSPECTION GAGES are inserted between the nut and body of a tube fitting after pull-up. If the GAP INSPECTION GAGE will fit in the gap between the nut and body hex, the fitting nut has not been tightened sufficiently.



Gap Inspection Gage fits between nut and body hex. Fitting *is not* sufficiently tightened.



Gap Inspection Gage does not fit between nut and body hex. Fitting *is* sufficiently tightened.

GYROLOK®
FLARELESS TUBE FITTINGS

ASSEMBLY INSTRUCTIONS

STEP 1

Insert the tubing resting it against the shoulder in the fitting body.

1.

STEP 2

Be sure the nut is finger tight. Now, simply tighten the nut 1¼ turns.

Hold the body of the fitting with a wrench or vise while turning the nut.

2.

TUBE MATERIAL

Various metallic, plastic and even glass tubing may be used with Gyrolok fittings. Nylon or Teflon® ferrules are available for use with glass tubing.

Fully annealed tube material is recommended. Stainless steel tubing having a hardness of less than Rockwell B90 should be used.

GYROLOK DIVISION OF HOKE INC., ONE TENAKILL PARK, CRESSKILL, N. J. 07626

GYROLOK®
FLARELESS TUBE FITTINGS

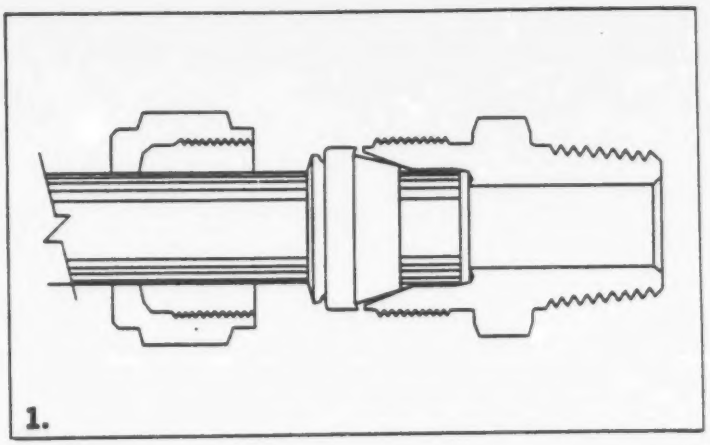
TUBE FITTINGS

REASSEMBLY INSTRUCTIONS

Gyrolok fittings may be assembled and disassembled repeatedly. The following instructions should be carried out to reassemble a fitting.

STEP 1

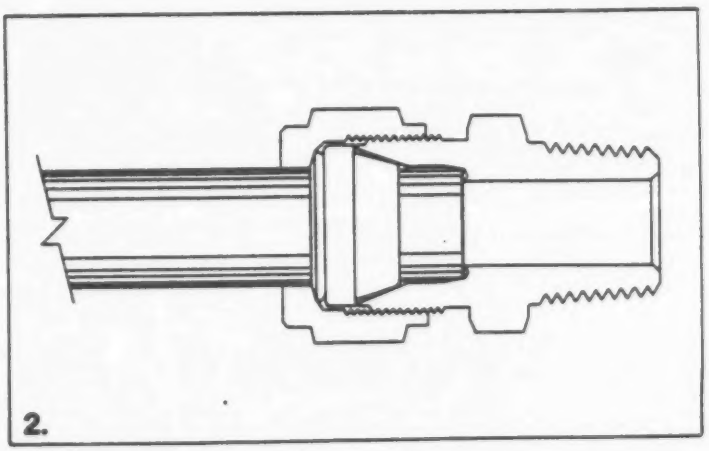
Insert the tubing end with the previously set ferrules into the fitting body and tighten the nut to a hand-tight condition.



1.

STEP 2

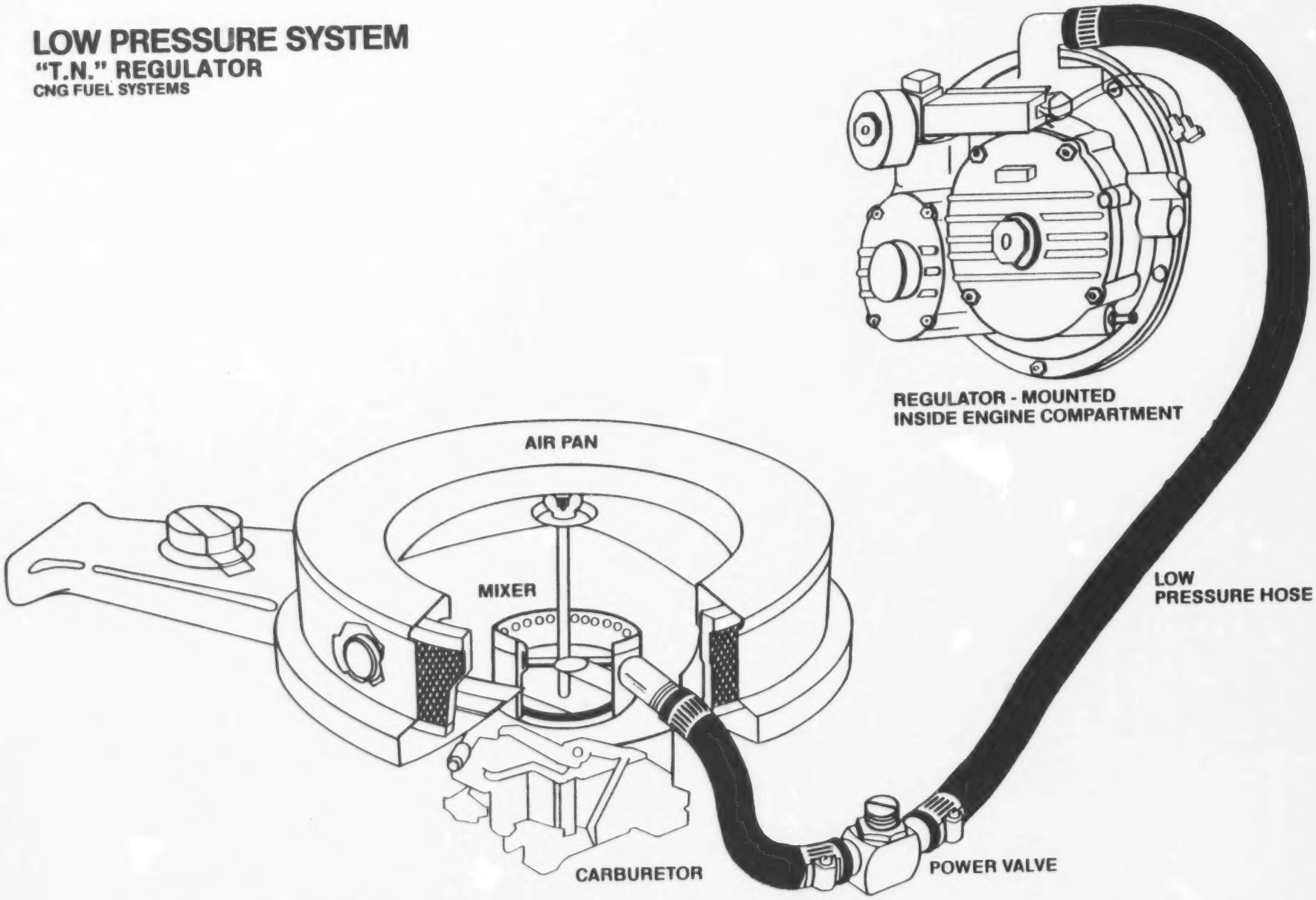
With a wrench, tighten the nut until a sharp rise in torque is felt. Then simply snug the nut.



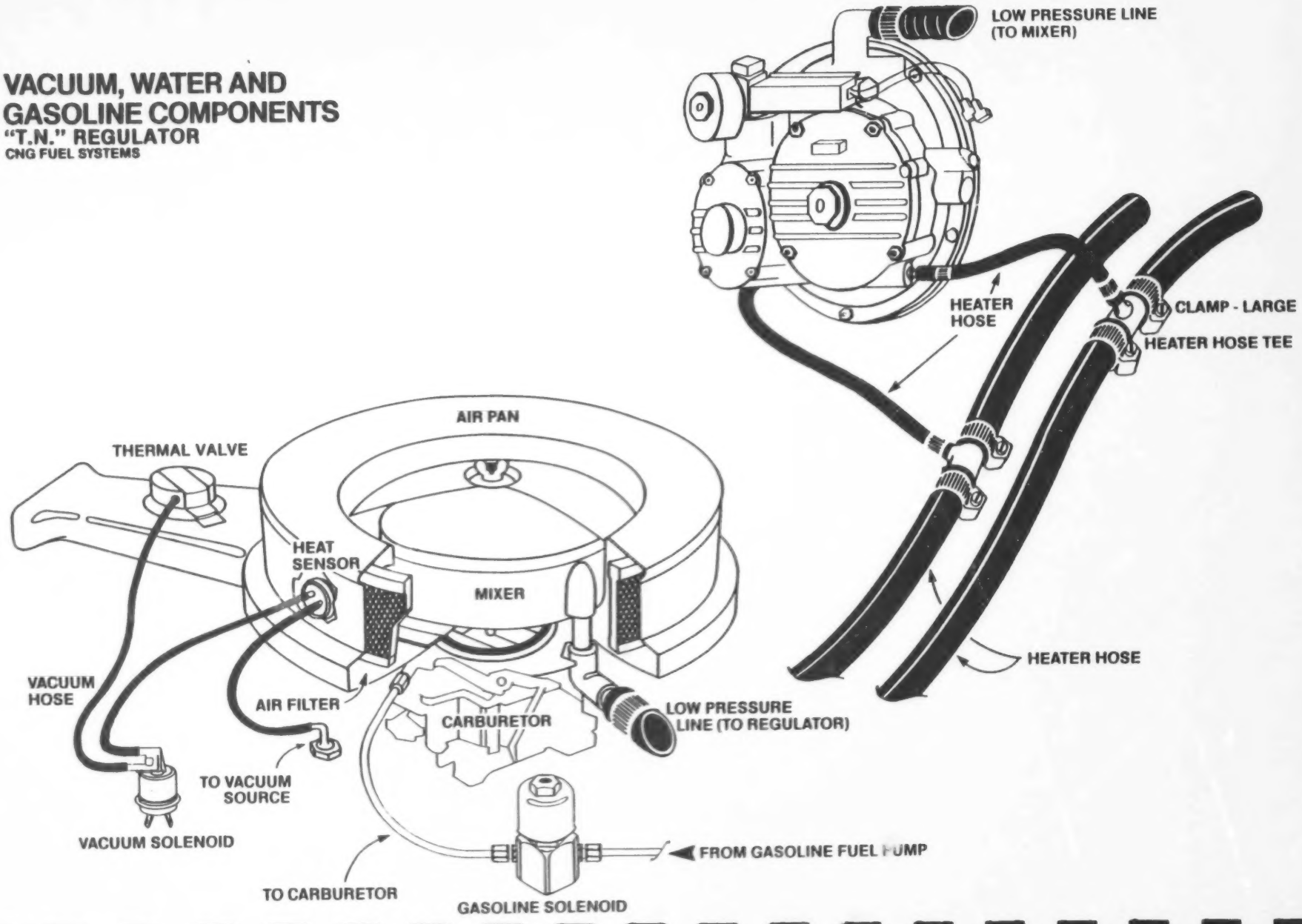
2.

YOUR NEAREST GYROLOK DISTRIBUTOR

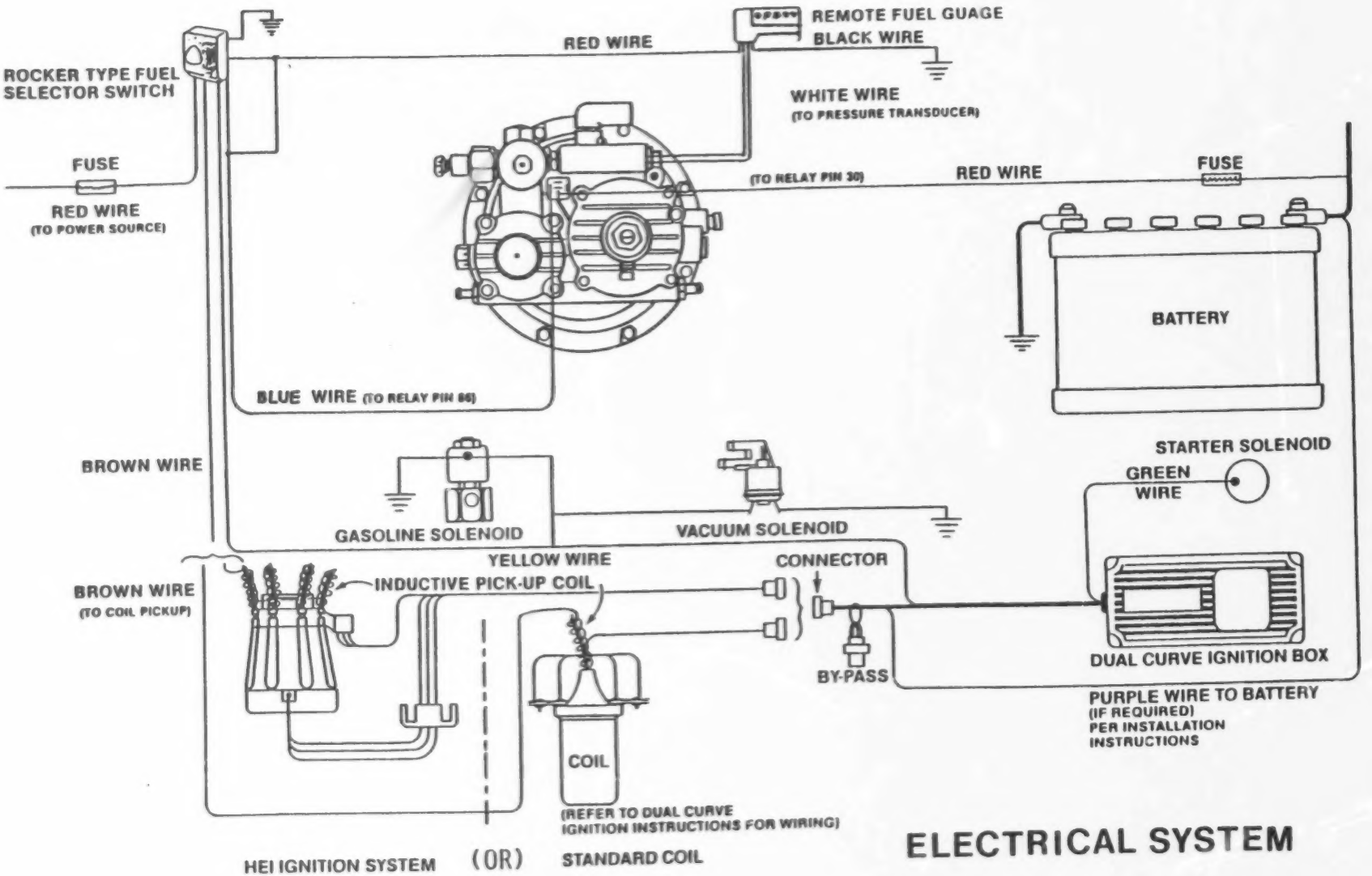
LOW PRESSURE SYSTEM
"T.N." REGULATOR
CNG FUEL SYSTEMS



VACUUM, WATER AND GASOLINE COMPONENTS
"T.N." REGULATOR
CNG FUEL SYSTEMS



APPENDIX "F"



ELECTRICAL SYSTEM

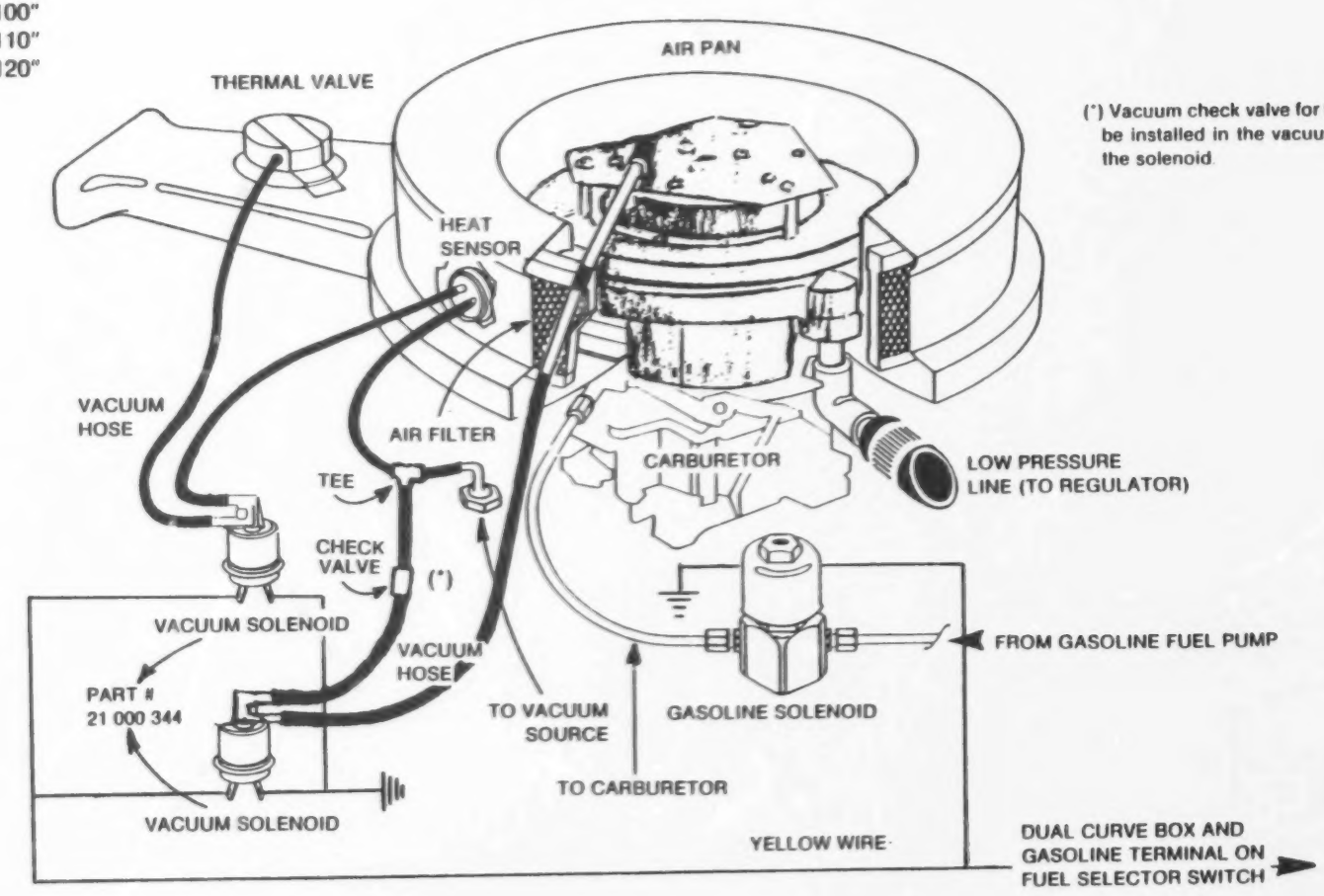
CNG FUEL SYSTEMS

VRI MIXER WITH AIR VALVE

APPENDIX "G"

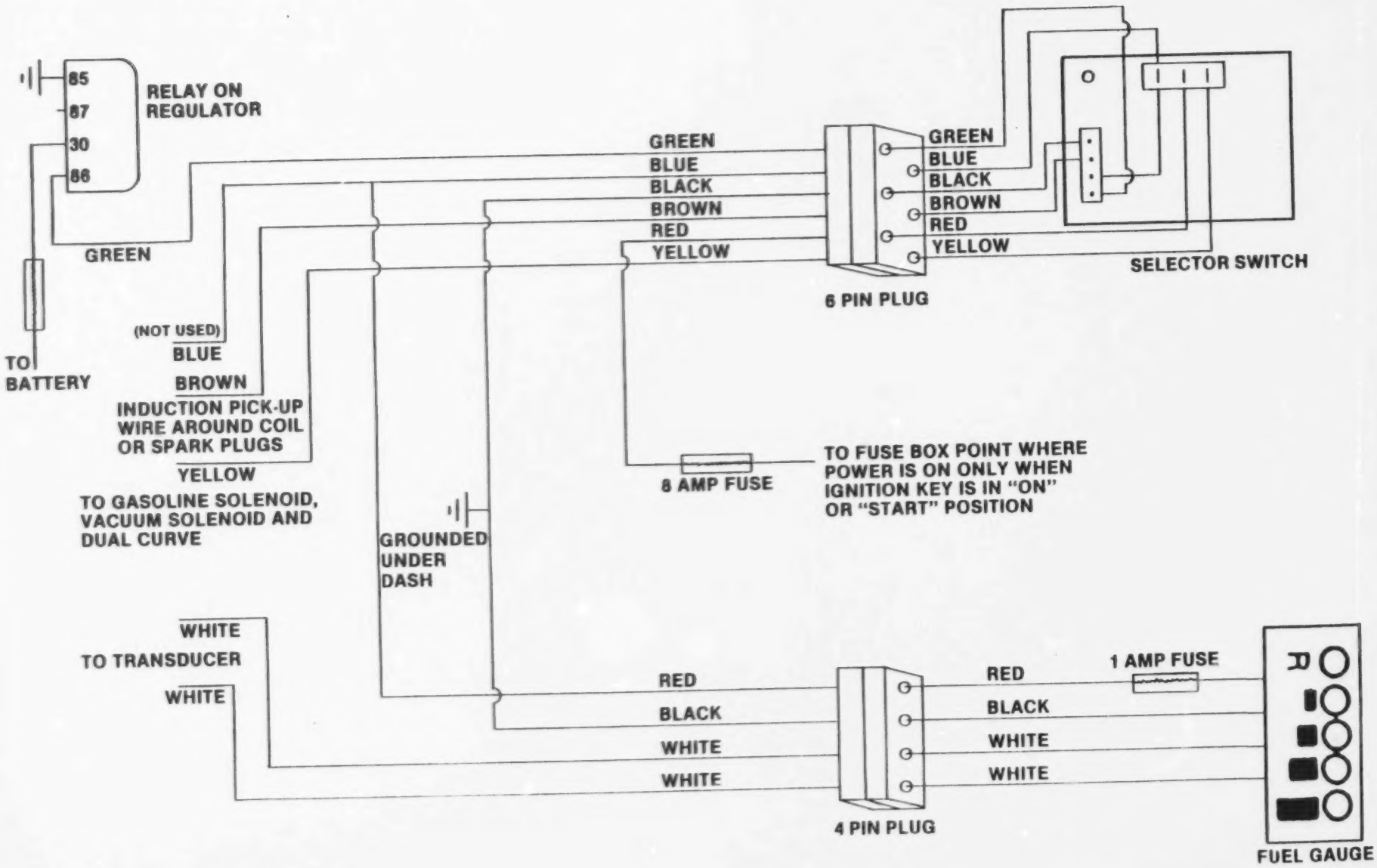
APPROXIMATE GAP FOR VRI

CID	GAP
300	.100"
350	.110"
400	.120"



(*) Vacuum check valve for the air valve must be installed in the vacuum source side of the solenoid.

CNG FUEL SYSTEMS



INSTALLATION INSTRUCTIONS

CNG/GASOLINE DUAL CURVE IGNITION

PART NO. 8794 - 8795 - 8796

THE PARTS KIT AS SUPPLIED WITH THIS UNIT ALLOWS CONNECTION TO ANY COIL HAVING THREADED STUDS OR TO THE FORD COIL. IF INSTALLATION IS TO BE MADE WITH THE GM HEI SYSTEM, A SPECIAL CABLE ASSEMBLY MUST BE PURCHASED. (PART NO. 8817 FOR THE UNITIZED MODEL OR PART NO. 8818 FOR THE SEPARATE COIL MODELS). THE 8818 CABLE MUST ALSO BE USED WITH THE FORD TFI IGNITION SYSTEMS. *CAUTION:* THE DUAL CURVE IGNITION WILL NOT OPERATE PROPERLY WITH THE ODD FIRE V-6 ENGINES. THIS INCLUDES MOST ALL 1977 AND EARLIER MODEL BUICK AND LATER MODEL ODD-FIRING CHEVY ENGINES SINCE THEN.

SINCE TIMING REQUIREMENTS CHANGE DEPENDING UPON THE NUMBER OF CYLINDERS, THREE MODELS OF THE DUAL CURVE IGNITION ARE MANUFACTURED. PART NO. 8790 IS FOR 8 CYL. MODELS, 8791 FOR 6 CYL. MODELS AND 8792 FOR 4 CYLINDERS.

USE THIS UNIT ONLY WITH A *STANDARD DISTRIBUTOR*. IF YOUR DISTRIBUTOR HAS BEEN MODIFIED FOR LPG OPERATION, IT MUST BE CHANGED BACK TO STANDARD. OTHERWISE ENGINE DAMAGE COULD RESULT.

THESE INSTRUCTIONS CONSIST OF FOUR MAJOR SECTIONS - ALL SECTIONS MUST BE COMPLETED FOR PROPER OPERATION.

SECTION I: INSTALLING THE DUAL CURVE UNIT
SECTION II: COIL PREPARATION AND HOOK-UP
SECTION III: TIMING AND TESTING
SECTION IV: TECH NOTES ON SPARK TIMING CURVES
SECTION V: HOOK-UP WITH ACCESSORY CABLES (GM HEI AND FORD TFI)

SECTION I: INSTALLING THE DUAL CURVE UNIT

The Dual Curve unit may be mounted in any location in the engine compartment except on the engine or near the exhaust manifold. Either of these locations could cause excessive heating of the unit. Make sure the cable will reach to the coil from the location selected. If the cable is too short, an extension cable, Part No. 8853 is available. Using the unit as a guide, mark the locations of two of the mounting holes at cross corners of the unit. Drill the holes using a ⅛" drill bit. Secure the unit with the self-tapping screws supplied in the parts kit. DISCONNECT THE BATTERY NEGATIVE CABLE TO AVOID SHORTING OUT BATTERY POSITIVE TO GROUND. Attach the Violet wire directly to the battery positive terminal or to the starter solenoid where the heavy cable from the battery is attached. THERE IS NO CURRENT DRAWN FROM THE BATTERY THROUGH THE VIOLET WIRE UNLESS THE IGNITION KEY HAS BEEN TURNED ON. The Green wire is to be attached to the START wire from the ignition key (voltage present on this wire only during start). The best place to find this voltage is at the starter solenoid. Do not connect the Yellow wire at this time. Directions for this wire are included in Section III of these instructions. IF YOU ARE MAKING A GM HEI OR FORD TFI INSTALLATION, GO TO THE INSTRUCTIONS FOR THE 8817 OR 8818 CABLE ASSEMBLY AT THIS POINT, OTHERWISE PROCEED TO SECTION II: OF THESE INSTRUCTIONS. ALSO READ ADDENDUM INSTRUCTIONS.

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SECTION II: COIL PREPARATION AND HOOKUP

IIA: INSTALLATION OF THE DUAL CURVE IGNITION WITH A THREADED STUD COIL

Prepare the coil with parts from the parts kit as shown in Figure 1. Use the red spacer on coil (+) and the black spacer on the negative side of the coil. Move all of the wires on coil (+) to the terminal on the outside of the red plastic spacer. On the coil (—) side, move only the breaker points or the electronic amplifier signal wire to the terminal on the outside of the black spacer. Any device which is normally attached to the (—) coil side of the coil (tachometer, water injection system, governor etc.) should be left on the coil (—) terminal of the coil.

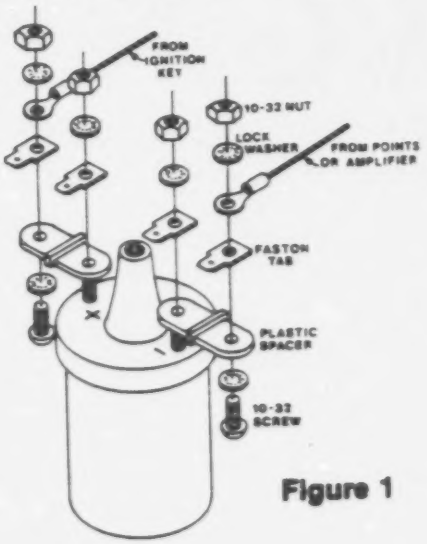


Figure 1

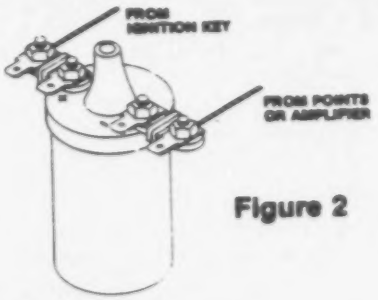


Figure 2

Figure 2 shows how the coil should look after the coil preparation has been completed.

The diagram below (Figure 3) shows the interconnection of the Dual Curve ignition unit with the internal wiring of the vehicle. Examine this diagram carefully to make sure everything is connected to the right place.

Figure 3a - INSTALLATION FOR DUAL FUEL OPERATION

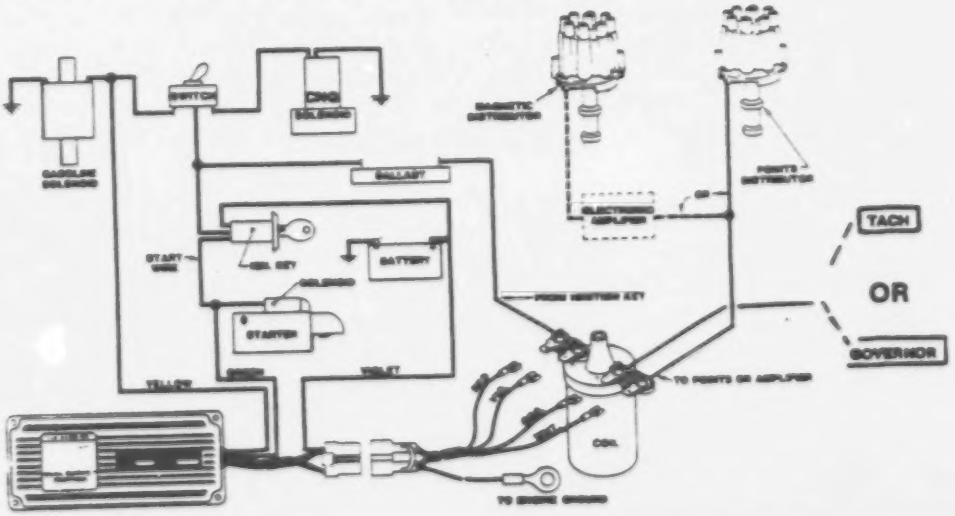
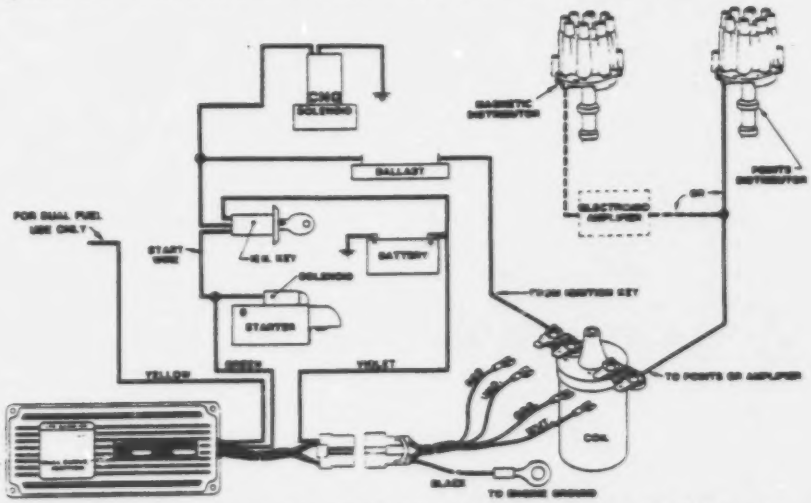


Figure 3b - INSTALLATION FOR SINGLE FUEL OPERATION



Push the faston receptacles on the Red, Violet, Orange and White wires on the faston tabs on the coil as shown. The Black wire with the ring terminal must be attached to a good ground, preferably on the engine block. Check for good factory engine-to-ground connection.

RECHECK WIRING CAREFULLY AND PROCEED TO SECTION III.

IIB: INSTALLATION OF THE DUAL CURVE IGNITION WITH A FORD TYPE COIL

Slide the horseshoe shaped connector off the coil and attach the cable assembly as shown in Figure 4. The Ford amplifier module is used to trigger the Dual Curve Ignition. Make sure that the white wire from the cable goes to the side of the horseshoe connector marked "TACH". The Red wire goes to the other side. NOTE: If "hot fast idle" occurs the vaccum "throttle kicker" electronics will require a Tach-a-Dapt. If factory tach or governor is present the Tach-a-Dapt Part No.8910 will be required or the control wire must be moved to coil(—).

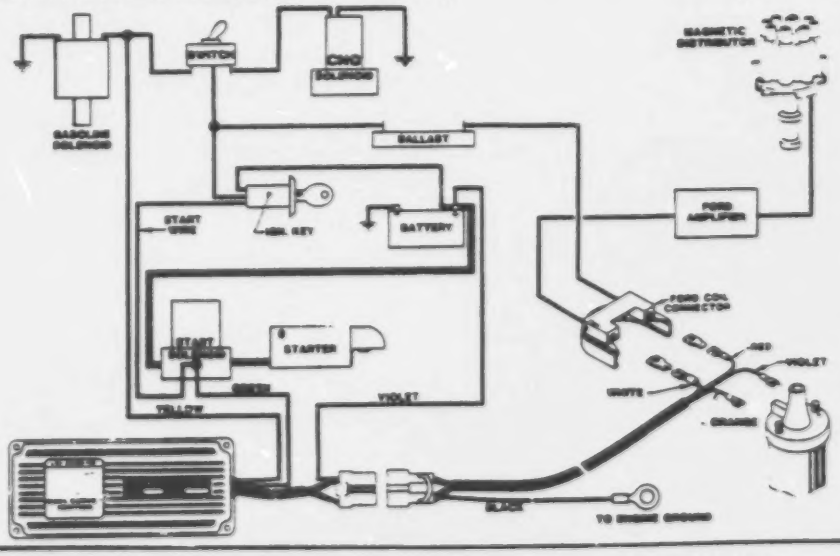


Figure 4a
FORD HOOKUP FOR DUAL FUEL OPERATION

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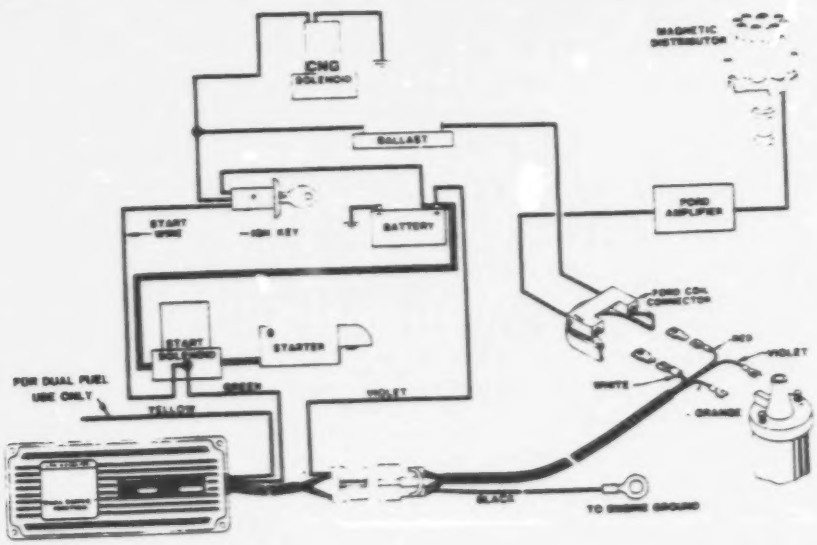
Figure 4b
FORD HOOKUP
FOR SINGLE FUEL
OPERATION



SECTION III: RE-TIMING, FINAL HOOK-UP AND TESTING

IIIA: Check out installation hook-up and operation of stock system.

1. Verify correct hook-up using Figures 1 and 3 or 4.
2. Insert the Jumper Plug into the Cable Connector as shown in Figure 6.
3. Disconnect and plug the vacuum advance hose.
4. Start the vehicle on either fuel.
5. Using a timing light, locate and check the stock timing. (check vehicle emission sticker for proper spark advance and special timing instructions). Make a record of this figure.
6. Speed up the engine and verify that the timing advances.
7. With the engine at about 1500 RPM, alternately connect and disconnect the vacuum advance, using the timing light to verify the vacuum advance is in good working order. Engines with computer spark control may not have a vacuum advance mechanism.
8. Stop the engine.

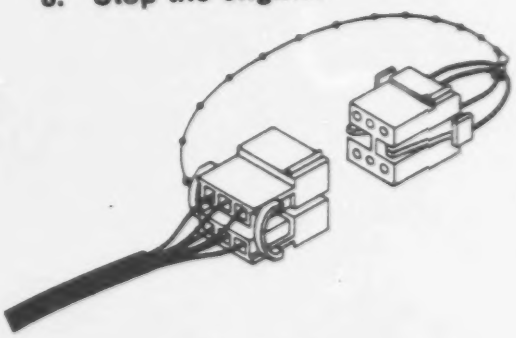


Figure 6

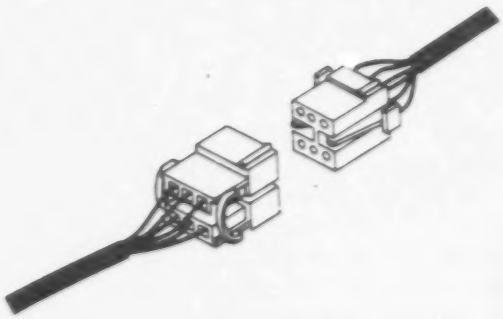


Figure 7

IIIB: Re-time the engine.

9. Disconnect the jumper plug from the coil connector.
10. Plug the unit cable assembly into the plug on the coil connector. See Figure 7. NOTE: It is recommended that MSD Spark Guard or a similar quality silicone lubricant be used in the connector on the unit cable prior to insertion into the coil connector. This will seal out any moisture from the connection.
11. TEMPORARILY connect the yellow wire coming out of the Dual Curve unit to the battery positive terminal or other constant 12V source. Leave connected until step 17.
12. Make sure that the vacuum advance hose has been left disconnected and plugged from step 3 above.
13. Start the engine on either fuel and run at factory spec. idle speed.
14. The timing setting as viewed with the timing light should now show approximately 15° of retard from the stock setting you observed in step 5.
15. Loosen the distributor hold-down and advance the timing by rotating the distributor until factory spec. timing is achieved.
16. Lock the distributor hold-downs.
17. With the timing light pointed at the damper/harmonic balancer, pull the yellow wire away from the 12 volt source. Verify that the timing advances approximately 12° at 1000 RPM on CNG.
18. Stop the engine.

IIIC: Final Hook-Up

19. Re-connect the distributor vacuum advance hose.
20. Connect the yellow wire from the Dual Curve Unit to the control wire which furnishes 12 volts to the gasoline fuel lock. Use the blue wire splice device from the parts kit. Directions for using the wire splice are shown in Figure 8.

IIID: Final System Check

21. Idle vehicle in the gasoline mode and note the timing setting.
22. Switch to the gaseous fuel at the conversion switch.
23. Check to insure that there is a substantial timing increase (at the same idle RPM as when in the gasoline mode). You should observe approximately 10° increase in advance.

USE OF THE TAP SPLICE

A wire tap device is supplied in the parts kit to enable the user to attach the Yellow wire directly to the wire which carries the control voltage to the Fuel Lock (See Figure 8).

Open and place the wire splice onto the Control Voltage wire going to the Fuel Lock (See Figure 8a). Close the wire splice and squeeze the two halves together with a pair of pliers. The metal tab will bite through the insulation and make contact to this wire (Figure 8b). Strip about ¼ of an inch of insulation off the end of the yellow wire coming from the Dual Curve ignition. Insert and crimp the yellow wire into the blue faston tab. Push the faston with the yellow wire attached into the end of the wire tap housing (Figure 8c). The connection has been made.

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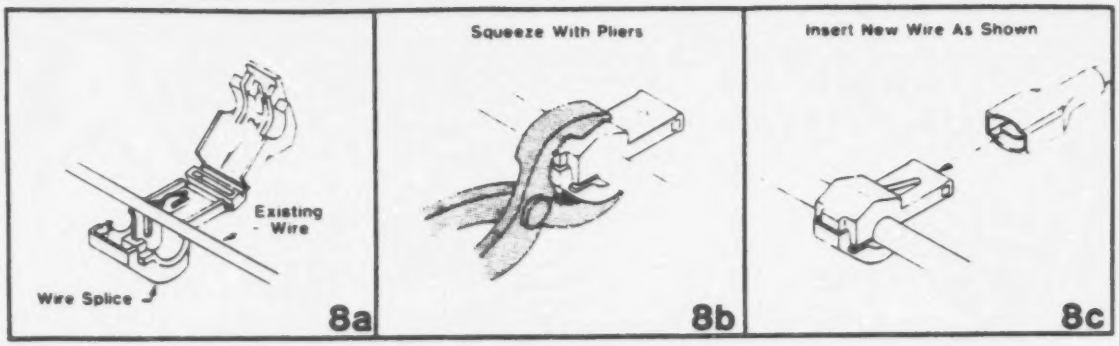


FIGURE 8

JUMPER PLUG

The jumper plug which you used during checks in Section III provides a means of returning to standard ignition in case of a malfunction. Insert the jumper plug. This will return your ignition system to standard operation. Just remember that your timing has been advanced too far for standard operation and should be readjusted as soon as possible. Operating in this mode, CNG is the best fuel to use. Drive slowly and carefully so as not to load the engine too heavily and readjust the timing as soon as possible.

SECTION IV:

TECH NOTES ON SPARK TIMING CURVES

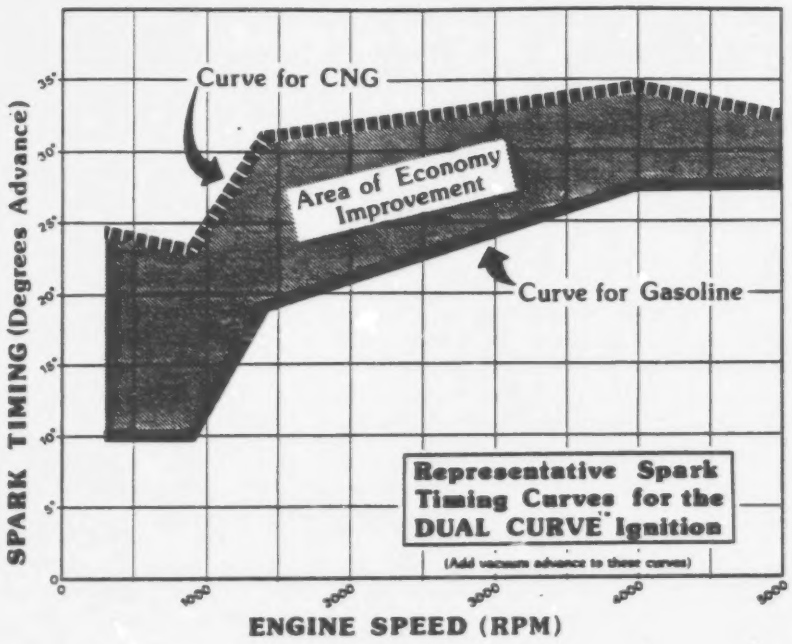
The Dual Curve computes the correct spark timing for CNG by using the engine's gasoline curve as a reference and adjusts for the difference in CNG's burning rate at any engine RPM.

The graph below shows two centrifugal spark timing curves without vacuum advance. The solid line curve is a generalized centrifugal gasoline advance curve and only represents an explanation of the Dual Curve's operation. This curve is a "map" of what any vehicle/engine combination likes on gasoline. This "map" will be used by the Dual Curve as a reference point to develop a CNG timing curve. The dotted line curve is the representative CNG timing curve that the Dual Curve computed for this combination.

The reasons for CNG requiring a different timing curve than gasoline are described below and are a function of the fuel's burning rate under a given set of circumstances. For maximum economy we want the pressure in the combustion chamber to push against the piston for as long as possible in the power stroke yet we want to prevent excessive combustion pressure from occuring during the compression stroke which would cause pinging or detonation and extremely high head temperatures.

CNG has a much higher octane rating than gasoline which indicates that it has a slower and more controlled burning rate. This allows us to advance the timing at low RPM's to gain added efficiency. Because of the controlled burning rate, CNG timing requirements are more consistent with engine speed. Gasoline on the other hand has a low octane rating and likes to detonate or ping at low engine speeds. At higher engine speeds, liquid gasoline does not have the time to change into vapor in the intake manifold, thus enters the combustion chamber as a liquid. Because the heat of compression must vaporize the fuel, combustion results in a slower flame travel. This is the reason for gasoline's increased timing requirements at higher RPM's and why its octane rating appears to increase with engine speed.

TECH NOTE ON SPARK TIMING CURVES
(continued)


Curve for CNG
Area of Economy Improvement
Curve for Gasoline
Representative Spark Timing Curves for the DUAL CURVE Ignition
(Add vacuum advance to these curves)
SPARK TIMING (Degrees Advance)
ENGINE SPEED (RPM)

The perfect engine design with the perfect fuel would have a constant spark advance at any engine speed for a given cylinder pressure. Since we control an engine's power output by means of throttling the intake, we still need to compensate for cylinder pressure. This is done with the vacuum advance. The change in burning rate from high mixture density (no vacuum, fast burning rate) to a low mixture density (high vacuum, slow burning rate) is similar for CNG and gasoline. A key to getting good fuel economy is having a properly working vacuum advance on both CNG and Gasoline and it is the reason we include its checkout as part of our instructions.

There is one more thing that affects mixture density and that is EGR (Exhaust Gas Recirculation). EGR increases the burn time and lowers the peak combustion temperatures. EGR provides a reduction of pollutants and also increases the fuel economy at light loads. There is a misconception that EGR hurts WOT (Wide Open Throttle) performance and this falsehood is easily dismissed by the fact that at WOT there is no vacuum to pull the EGR valve open. Because the engine Manufacturer knows that EGR slows the burning rate of the fuel mixture, they increase the slope of the vacuum advance to compensate. This is the reason an engine which has had the EGR valve disconnected likely finds itself with a light load detonation problem and a loss of economy.

It is best to start the vehicle's timing as close to stock as possible. Check the advance curve (vacuum advance connected) at 3000 to 3500 RPM (no load) and record. Many engines do not like an advance of over 55 degrees on CNG, especially one that has high compression or is in a heavy duty application. On these engines it is best to readjust the distributor to give 55 degrees of advance. After this is done, test drive. Listen for detonation with a hot engine under heavy load. If detonation is present it may be that you are running spark plugs with a heat range that is too hot for the application. To check, retard the timing a few more degrees. If detonation is still present, then it is likely that you must go to a colder spark plug instead of retarding the timing. Also check for a plugged EGR valve.

These tests are worth making, even though the majority of the installations won't have any problems. You should also be certain that your timing light is accurate and that you measure the timing correctly.

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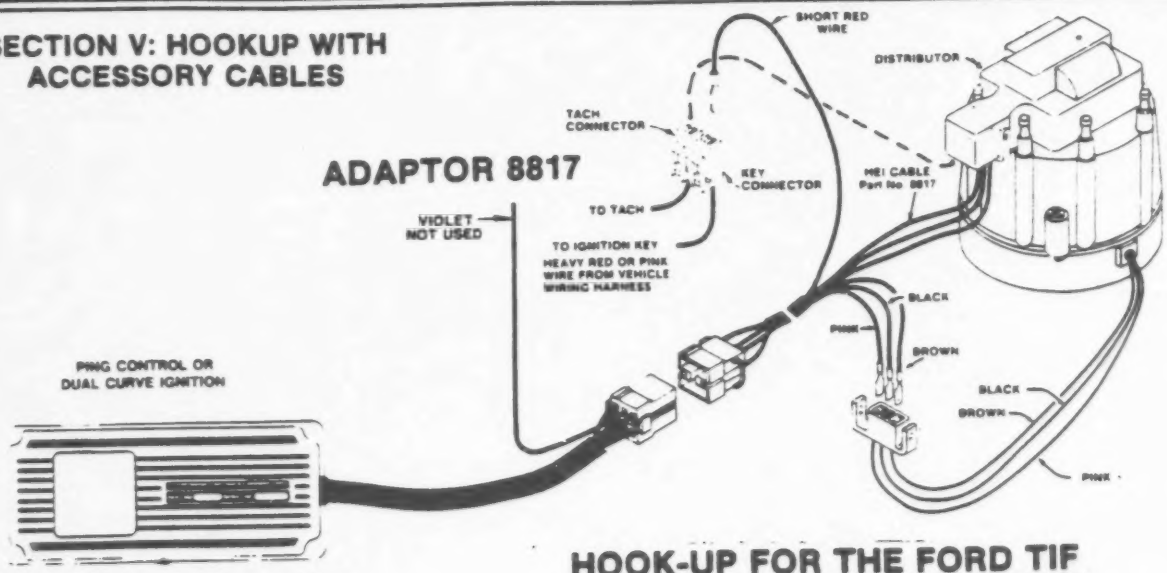
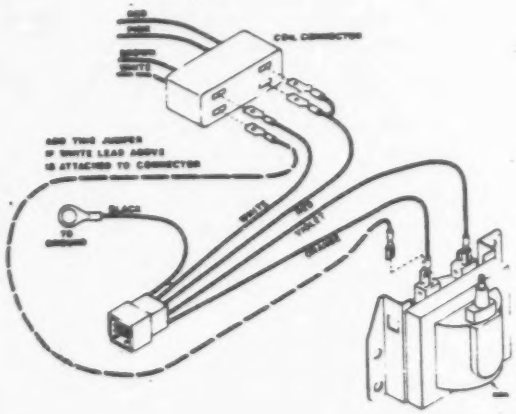
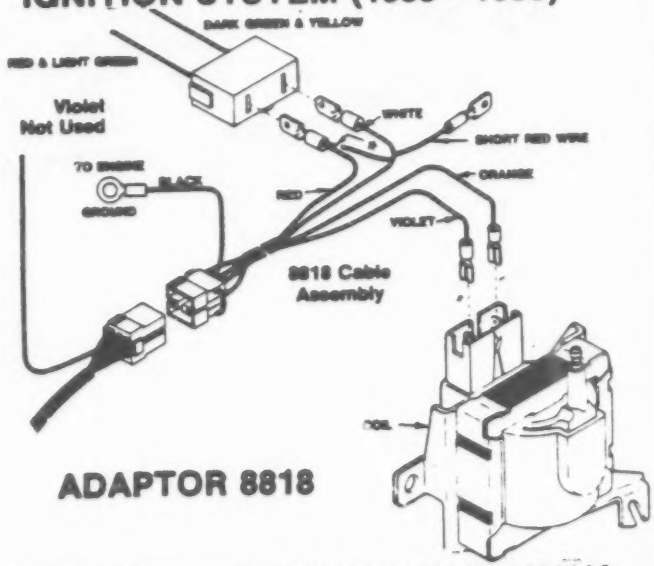
SECTION V: HOOKUP WITH ACCESSORY CABLES



HOOK-UP FOR THE GM REMOTE COIL ADAPTOR 8818



HOOK-UP FOR THE FORD TIF IGNITION SYSTEM (1983 - 1985)



ADAPTOR 8818

☆ LIMITED WARRANTY ☆

Autotronic Controls Corporation warrants this product to be free from defects in material and workmanship under normal use and if properly installed for a period of one year from the date of purchase. If found to be defective as mentioned above, it will be replaced or repaired if returned prepaid along with proof of date of purchase. This shall constitute the sole remedy of the purchaser and the sole liability of Autotronic Controls Corporation. To the extent permitted by law, the foregoing is exclusive and in lieu of all other warranties or representations whether expressed or implied, including any implied warranty of merchantability or fitness. In no event shall Autotronic Controls Corporation be liable for special or consequential damages.

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